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PALAEOENVIRONMENTAL ANALYSIS OF THE MESSINIAN MACROFOSSIL FLORAS OF TOSSIGNANO AND MONTE TONDO (VENA DEL GESSO BASIN, ROMAGNA APENNINES, NORTHERN ITALY)

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Abstract. Fossil leaves of Messinian age (ca. 5.7 Ma) from two sites of the Vena del Gesso Fm. (Monte Tondo and Tossignano, Ravenna and Bologna provinces, Italy) were studied morphologically to assess the taxonomic composition of the assemblages and carry out a palaeoenvironmental analysis. The flora of Tossignano so far comprises 41 vascular plant taxa with 8 conifers and 33 angiosperms (30 dicots and 3 monocots). In the plant material from Monte Tondo 74 vascular plant taxa were recognized, with 11 conifers and 63 angiosperms (59 dicots, 3 monocots, 1 plant incertae sedis). Several fossil species well known in the Miocene of central Europe and Italy were detected. The most frequent being *Taxodium dubium*, *Pinus* cf. *rigios*, *Daphnogene polymorpha*, *Laurophyllum* sp. 1 and 2, *Platanus leucophylla*, *Quercus pseudocastanea*, *Quercus roburoides*, *Fagus gussonii*, cf. *Ailanthus pythii*, Leguminosae gen. et sp. indet. 1. The general palaeovegetation pattern of the Monte Tondo and Tossignano plant assemblages correspond to the vegetation transect of the Evaporitic Messinian with swamp, riparian vegetation, and zonal "subtropical humid forest". The results of IPR vegetation analysis for the "subtropical humid forest" zone indicate a transitional (ecotone) vegetation type between "Broad-leaved Evergreen Forest" and "Mixed Mesophytic Forest". The Coexistence Approach estimates that both floras existed under comparable climatic conditions, with MAT 14–16.2 °C for Tossignano and 16–16.5 °C for Monte Tondo. This is warmer than the estimates derived from the Leaf Margin Analysis (MAT 13.8 °C and 14.3 °C) and Climate Leaf Analysis Multivariate Program (MAT 13.2 °C and 12.0 °C), and present day conditions in the Mediterranean Zone (MAT around 13.5 °C).

■ flora, vegetation, palaeoclimate, Messinian, Italy.

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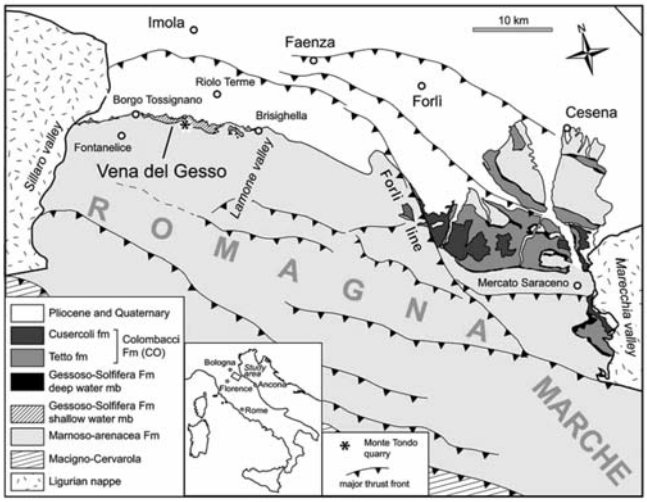
Introduction

Messinian sediments assigned to the Vena del Gesso Fm., previously called "Gessoso-solfifera Formation" (Roveri and Manzi 2007), crop out extensively in the western Romagna area. The presence of fossil plants in a few outcrops has been known since the mid-nineteenth century: the great geologist from Imola, Giuseppe Scarabelli, wrote "... in a thin layer of shaly marl, alternating with the gypsum of Tossignano, a nice imprint of *Cinnamomum polymorphum*, so abundant in Senigallia and Stradella, a species of *Fagus* and various fragments of indeterminable *Quercus* (...) were found" (Scarabelli 1864). Subsequently, at the beginning of the 20th century Paolo Principi reported that in the surroundings of Brisighella town he found "... between the gypsum beds some thin clayey marl layers with (...) plant remains, some of them attributable to *Taxodium distichum miocenicum* Heer, *Glyptostrobus europaeus* Heer, *Arundinites goeppertii* Principi, *Quercus proteifolia* Paolucci, *Cinnamomum polymorphum* Heer, *Planera ungeri* Ettingshausen..." (Principi 1942).

In the Museum of Natural Sciences in Faenza (MSF) a remarkable collection of fossil leaves of Messinian age is



Text-fig. 1. Location of the Tossignano and Monte Tondo sites in the Romagna Apennines (modified after Lugli et al. 2010). 1 – Tossignano quarry, 2 – Monte Tondo quarry.

housed, collected over the years at two different sites, Tossignano (municipality of Borgo Tossignano, Bologna province) and Monte Tondo (municipality of Riolo Terme, Ravenna province), only a few kilometres apart and both with exposed the Vena del Gesso Fm. The name "Vena del Gesso" is also a popular name for a continuously outcropping gypsum belt extending in a northwest-southeast direction for some 15 km in the western Romagna Apennines and which offers spectacular outcrops of selenitic Messinian gypsum (Roveri et al. 2006). The story of the two collections is substantially different: the core of the Tossignano palaeoflora is the fossil collection that P. Viaggi donated to MSF in 1983 (Viaggi 1989). This collection, consisting of some hundreds of fossils (especially fishes and leaves), was recovered by the donor between the years 1976–1982 from an outcrop in the SPES gypsum quarry (Text-fig. 1). This quarry, located on the right side of a small canyon created by the Sgarba creek, remained in operation from 1969 to 1986. Other specimens were added to the initial collection during subsequent years, always recovered from the same location, thanks to various volunteers of MSF, including in particular M. Diversi. The recovery of the Monte Tondo palaeoflora occurred much more recently (during 2012–2014) as a result of the multidisciplinary project initiated by the Speleological Federation of Emilia Romagna. This was concentrated on the gypsum area immediately to the south of the town of Borgo Rivola, which had been subjected to intense mining activity since 1958 (Text-fig. 1). Through this project some MSF volunteers (i.e., one of the authors, M.S., ably assisted by T. Benericetti) had the opportunity to sample a site in which decades of digging had made difficult to access. This field work produced several hundreds of fossil leaf samples, in addition to fossil remains of fishes and insects.

The palaeoflora from Tossignano, although already known since the second half of the 19th century (Scarabelli 1864), was also later quoted in a few other general palaeobotanical papers (e.g., Knobloch and Gregor 1997, Kovar-Eder et al. 2006, Bertini and Martinetto 2008, 2011). The palaeoflora of Monte Tondo was first described in a preliminary study by Sami and Teodoridis (2013).

Geological setting

The Romagna Apennines, extending from the Sillaro valley on the west to the Marecchia valley on the east, are part of the northeast-verging Northern Apennine arc and are characterized by an exposed belt of siliciclastic deposits of early Miocene to Pleistocene age, overlying buried Mesozoic to Cenozoic carbonates. The uppermost structural unit cropping out along the Po Plain side of the Romagna Apennines consists of the Langhian to Tortonian Marnoso-arenacea Formation turbiditic complex (Ricci Lucchi 1975, 1981) while the Apennine foothills are a gentle northeast dipping monocline of Messinian to Pleistocene deposits resting above the Marnoso-arenacea Fm. The Tortonian–Messinian succession of the Apennine orogenic wedge records the fragmentation and closure of the Marnoso-arenacea foredeep basin during the extended thrust-front propagation and concurrent depocenter migration toward the foreland (Ricci Lucchi 1986). This process implied the formation of small thrust-top basins; some of them were characterized during the Messinian by the deposition of shallow-water, primary evaporites (mainly selenitic gypsum), coeval with the Lower Evaporites of Mediterranean marginal basins (Krijgsman et al. 1999a, b). However, these basins are rarely preserved because of subsequent tectonic deformation thus the Vena del Gesso basin is a valuable exception.

Stratigraphy

The Romagna Apennines are split into two sectors (western and eastern) by the Forlì line, a deformational zone characterized by reverse faults orientated obliquely to the Apenninic trend that played a primary role in the geologic evolution of the area, at least since the late Tortonian (Ricci Lucchi 1986). The Langhian to Pliocene sedimentary succession of the western Romagna Apennines (in which the Vena del Gesso is situated) has been classically subdivided into four lithostratigraphic formations (Vai 1988; Text-fig. 2):

1. The Marnoso-arenacea Formation (Tortonian–Messinian), made up of deep-water siliciclastic turbidites mainly derived from Alpine sources, is the infill of a large foredeep basin elongated in a northwest-southeast direction, whose depocenter shifted through time, following the northeastward propagation of the compressional front. The upper part of this unit consists mainly of slope mudstones (informally named "ghioli di letto" by previouse authors) containing minor turbiditic sandstones and chaotic bodies; these rocks are in turn overlain by a thin horizon characterized by cyclically interbedded organic-rich laminites and mudstones, informally referred to as "euxinic shales" (upper Tortonian–lower Messinian). Like the coeval Tripoli Formation in Sicily and Spain, such deposits, consisting of organic- and diatomite-rich laminites, record palaeoceanographic changes that heralded the Messinian salinity crisis. The euxinic shale unit, straddling the Tortonian/ Messinian boundary, spans a 1.5 Ma time interval, characterized by well-defined biomagnetostratigraphic events; their calibration with astronomical cyclicity allowed a detailed chronostratigraphy to be established (Krijgsman et al. 1999a, b, Vai 1997).

2. The Vena del Gesso Fm. (Messinian), is made up of primary evaporites with interbedded organic-rich shales, deposited during the evaporitic stages of the Messinian salinity crisis.

3. The Colombacci Fm. (upper Messinian), consisting of siliciclastic sediments derived from Apenninic sources, was deposited in shallow and deep, brackish or freshwater basins developed during the final phase of the Messinian salinity crisis (Lago-Mare phase).

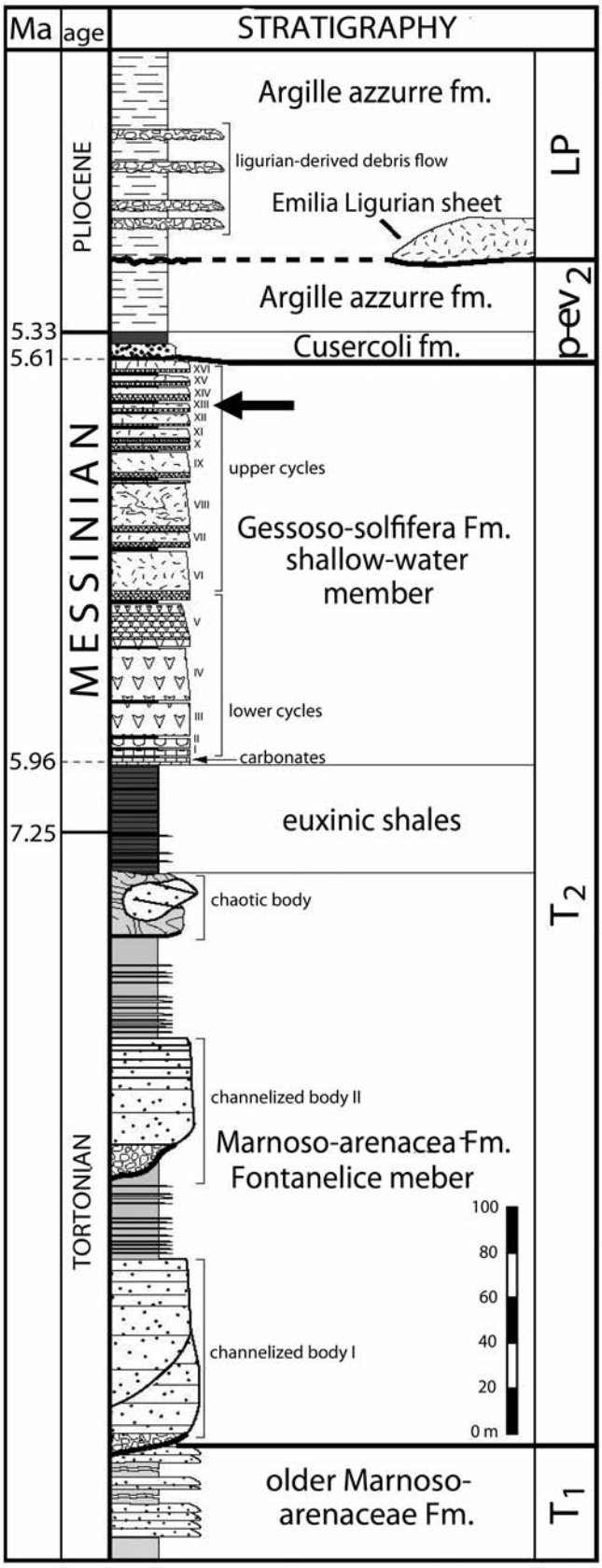
4. The Argille Azzurre Fm. (lower Pliocene) is made up of mudstones deposited in a relatively deep marine environment. They locally encase conglomerate and sandstone bodies and small, isolated carbonate platforms (locally named Spungone).

In particular, for primary in situ Messinian evaporites of the Vena del Gesso Fm. a maximum thickness of 150 m is attained in the central area of the outcrop (between the Santerno and Sintria valleys). Up to 16 small, decimeter-scalethick, shallowing-upward cycles have been recognized. The typical cycle is characterized by the vertical superposition of some sedimentary facies (Vai and Ricci Lucchi 1977). The "ideal" complete evaporitic cycle starts with basal organic-rich shales (with fossil remains of leaves or fishes) that are overlain by stromatolites replaced by gypsum and, in turn, by well stratified selenitic gypsum, then banded selenite and, on the top, the so-called branching selenite. These cycles, once thought to be related to the progressive evaporations of shallow lagoons ending with subaerial exposure and erosion (Vai and Ricci Lucchi 1977), have more recently been considered as small scale subacqueous sedimentary cycles characterized by brine level oscillations that mimic regressive-transgressive cycles in a restricted marginal basin (Lugli et al. 2010).

Like the underlying euxinic shales, the primary lower gypsum deposition was cyclical (shale/selenite cycle) and probably controlled by periodic changes of orbital parameters such as astronomical precession (Vai 1997, Krijgsman et al. 1999b): each cycle would thus record a time span of about 21,000 years. According to this interpretation, evaporite deposition occurred during precession maxima (insolation minima), during relatively dry periods when evaporation exceeded precipitation. The shale interlayers separating the selenite beds are on the contrary correlated with the humid period of the precession climatic cycle (precessional minima, insolation maxima).

The timing of Messinian events proposed by Krijgsman et al. (1999a), on the basis of a detailed astronomically calibrated cyclostratigraphy, pointed to their remarkably synchronous character throughout all the Mediterranean (Italy, Spain, Greece and Cyprus) despite the different geodynamic and depositional settings of evaporites: in particular, the onset of the Lower Evaporite deposition has been dated to ca. 5.96 Ma and its end to 5.61 Ma.

A progressive vertical change in the thickness and facies distribution within the individual cycles can be observed; the upper cycles are thinner than those at the base, and the relatively deeper-water facies units are significantly less well developed than the clastic facies. This change suggests that an overall ''regressive'' trend is superposed on the smaller-scale, higher-frequency cyclicity; this longer-term trend culminates with the great erosional unconformity that cuts



Text-fig. 2. Stratigraphy of western part of the Romagna Apennines (after Roveri et al. 2006). Symbol "arrow" – stratigraphical position of the studied floras of Tossignano and Monte Tondo.

the uppermost gypsum unit, associated with an angular unconformity clearly indicating its tectonic nature (Vai 1988). It is well known from regional geological studies that

the intra-Messinian event is one of the most important in the evolution of the Apenninic orogenic wedge, marking a significant migration of the whole compressive front and associated foredeep basin toward the foreland, i.e., the Po Plain. Along with this surface, evidence of prolonged subaerial exposure (karstic dikes filled by continental deposits rich in mammal fossils) has been found in the Monticino section near Brisighella (De Giuli et al. 1988). The erosion associated with the Messinian/Pliocene unconformity increases toward the southeastern end of this sector (Lamone valley), where evaporitic and preevaporitic Messinian deposits are almost completely absent.

Material and methods

In the Vena del Gesso basin fossils are exclusively preserved in organic-rich laminated shale layers, generally less than 1 m thick, which separate the selenite beds. As mentioned above, the presence of these shale partings (or interlayers) testifies to the cyclical flooding of the evaporite basin by undersaturated continental waters (Lugli et al. 2010) and, according to Krijgsman et al. (1999b), it should represent the expression of the humid periods that were cyclically interrupted by evaporite deposition. The presence of well-preserved fishes and plant remains, the absence of megabenthos and the lamination of the shales suggest that persistent anoxic conditions occurred at the bottom of the basin (Landini and Sorbini 1989, Carnevale et al. 2008, Sami and Teodoridis 2013).

Field observations carried out by one of us (M.S.) indicate that in the Tossignano and Monte Tondo sites almost all interlayers are fossil-bearing deposits and bear traces of plant remains. But the majority of fossils are concentrated between the 12th and 13th evaporitic cycles (see Text-fig. 2), although a small part of the collection has a doubtful stratigraphic position (Viaggi 1989). According to the astronomically calibrated cyclostratigraphy of Messinian events (Krijgsman et al. 1999a), each gypsum sapropel cycle would have a duration in the order of about 21,000 years so it is possible to define the age of the fossil material reported in this paper to approximately 5.70 Ma (Carnevale et al. 2008).

At Tossignano, plant fossils are mostly complete, not fragmented, and the very fine grain size of the clayey matrix and the poor oxygenation of the ancient bottom favoured relatively good preservation of leaf remains, often still bearing their organic cuticle (Viaggi 1989). While in the Monte Tondo site the plant fossils (especially leaves) are mostly fragmentary, which seems to reflect a typical situation related to pre-burial river transport, with a parautochtonous to allochthonous assemblage. In addition, at Monte Tondo the stresses induced by an intense tectonic disturbance caused the fragmentation of the fossil-bearing deposits in tight polyhedral blocks which hampers the collection of entire fossils.

To obtain independent palaeoenvironmental estimates for Monte Tondo and Tossignano, five different palaeoenvironmental methods were used: Phytosociological approach (Mai 1995), Integrated Plant Record vegetation analysis (IPR-vegetation analysis – Kovar-Eder and Kvaček 2007), Climate Leaf Analysis Multivariate Program (CLAMP – Wolfe and Spicer 1999), Leaf Margin Analysis (LMA – Su et al. 2010) and Coexistence Approach (CA – Mosbrugger and Utescher 1997). Symbols for distinguishing vegetative storeys and palaeoclimate parameters are as follows: E1 (herbs and vines), E2 (shrubs and lianas), E3 (trees under 25 m high) and E4 (trees over 25 m high); MAT (Mean Annual Temperature), WMMT (Warmest Month Mean Temperature), CMMT (Coldest Month Mean Temperature), 3-WET (Precipitation during 3 Consecutive Wettest Months), 3-DRY (Precipitation during 3 Consecutive Driest Months), MPwet (Mean Precipitation in the Wettest Month), MPdry (Mean Precipitation in the Driest Month), MPwarm (Mean Precipitation in the Warmest Month) and MAP (Mean Annual Precipitation).

Systematic palaeontology

Arrangement of taxa is according to Christenhusz et al. (2011) and Reveal (2012).

Conifers
Pinaceae Lindley

Pinus Linnaeus
Pinus sp. (cone)

Pl. 1, Fig. 1

A symmetric ovoid seed cone, 55 mm long and 25 mm wide, strongly abraded, which does not show details of the apophyses. In its general form it conforms with the late Miocene record of *P. hampeana* (Unger) Heer based on a single seed cone from Vegora, Greece (Mai and Velitzelos 1997). In Italy, better preserved material was assigned to *P. hampeana* from Pliocene sediments, e.g., in Tuscany (Meleto Clay: Mai 1994, Fischer and Butzmann 2000) and Piedmont (Martinetto 1995).

Material. One seed cone (Tossignano MSF55) and fragment (Monte Tondo MSF1867).

Pinus sp. div. (seed)

Pl. 1, Fig. 5

Winged seeds occurring in isolation. Seed not preserved, probably elliptical, up to 3 mm long, located basipetally and symmetrically, adnate to wings. Wings slightly oval to obovate in outline, up to 16 mm long, wing apex asymmetrical, rounded, striation distinct and parallel.

Winged seeds belonging to pines, most probably to the same taxon that produced the above seed cone.

Material. Seeds (Monte Tondo MSF1869, MSF1870, MSF1871).

Pinus cf. *rigios* (Unger) Ettingshausen

Pl.1, Fig. 2–3

Needles of an incomplete length measuring more than 120 mm, joined in 2 to 3 per fascicle; sheaths preserved sometimes at the fascicle base. The specific determination is doubtful. Similar needles were distinguished in two fossil species in the Meleto Clay by Fischer and Butzmann (2000),

but the number of needles per fascicle often varies between 2 and 3 in the same species in the subgen. *Pinus*.

M a t e r i a l . Impressions of pine needles (Monte Tondo MSF1851, MSF1852, MSF1853, MSF1854, MSF1855, MSF1856, MSF1857, MSF1858, MSF1859, MSF1860, MSF1861, MSF1862, MSF1863, MSF1864; Tossignano MSF228, MSF45).

Pinus paleostrobus Ettingshausen

Pl. 1, Fig. 4

Fascicles of needles joined in 5 per fascicle, lacking sheaths, less than 1 mm thick, more than 120 mm long. Foliage most probably belongs to subgen. *Strobus* (D. Don) Lemmon.

M a t e r i a l . Impressions of pine needles (Monte Tondo MSF1865, MSF1866; Tossignano MSF36).

Pinaceae gen. indet.

Pl. 1, Fig. 6

A detached single needle, flat, single-veined, not identifiable to a genus on gross morphology.

M a t e r i a l . One needle (Tossignano 4659).

Cupressaceae Gray

Taiwania Hayata
Taiwania sp.

Pl. 1, Figs 7–8

Short leafy branchlet with flattened falcate needles, up to 95 mm in length, irregularly helically disposed, similar to branches identified as *Taiwania schaeferi* Schlomer-Jäger by Fischer and Butzman (2000, pl. 6, figs 1–2) and as *Taiwania* sp. by Velitzelos et al. (2014).

M a t e r i a l . Fragmentary branchlets (Monte Tondo MSF1954, MSF1955, MSF1956, MSF1957, MSF1958, MSF1959, MSF1960, MSF1961, MSF1962, MSF1963, MSF1964, MSF1965, MSF1966; Tossignano MSF39, MSF233, MSF237, MSF238).

Sequoia Endlicher
Sequoia sp.

Pl. 1, Figs 9, 12

Leafy twigs covered by scale-like, spirally arranged leaves, closely adhering to the axis or just slightly protruding, differently sized, up to 44 mm long. Needles linear to lanceolate, apex acute, base shortly petiolate and rounded, venation with strong, distinct midrib, often visible dense parallel venation. Winged seed ovate in outline, flattened, 7 mm long and 4 mm wide, curved, base and apex rounded, margin slightly undulate, seed cavity central oblong, 1.5 mm wide, longitudinally furrowed, chalaza and micropyle not distinct, bordered by bifacial asymmetric wings.

Morphologically similar leaf twigs are known from the late Miocene flora of Vegora (Kvaček et al. 2002), where they are also associated with *Taxodium* leafy shoots. The seed shows morphologically affinity to the genus *Sequoia* rather than *Quasisequoia couttsiae* (Heer) Kunzmann (see Pingen 1994).

M a t e r i a l . Leafy twigs (Tossignano MSF225, MSF232, M. D. IMG_4667, M. D. IMG_4656), seed (Monte Tondo MSF1953).

Glyptostrobus Endlicher
cf. *Glyptostrobus* sp.

Pl. 1, Figs 10, 11

Branched or unbranched twigs of varying sizes up to 62 mm, with helically disposed adpressed scales leaves as well as cryptomerioid foliage. Identification is equivocal without any anatomical evidence. The occurrence of *Glyptostrobus europaeus* (Brongniart) Heer was indicated by Kovar-Eder et al. (2006) in several Messinian sites in Italy and also in Greece (Vegora) by Kvaček et al. (2002).

M a t e r i a l . Unbranched and branched twigs (Tossignano MSF235, MSF236).

Taxodium Richard
Taxodium dubium (Sternberg) Heer

Pl. 1, Fig. 13

Elongate leafy shoots, with distichous flat needles, varying sizes up to 60 mm. Needles alternate at unequal distances, linear to lanceolate, apex acute, base often very shortly petiolate and rounded, venation with strong and distinct midrib, rarely visible dense parallel venation, occasionally perennial macroblast with spiral imbricate needles up to 120 mm. The occurrence of *Taxodium dubium* was indicated by Kovar-Eder et al. (2006) in several Messinian sites in Italy.

M a t e r i a l . Impressions of shoots (Monte Tondo MSF1967, MSF1968, MSF1969, MSF1970, MSF1971, MSF1972, MSF1973, MSF1974, MSF1975, MSF1976, MSF1977, MSF1978, MSF1979, MSF1980, MSF1981, MSF1982; Tossignano MSF37, MSF42, MSF52, MSF225, MSF226, MSF227, MSF229, M. D. IMG_4670, M. D. IMG_4674)

Chamaecyparis Spach
Chamaecyparis sp.

Pl. 1, Figs 14, 15

Branched plagiotropic leafy shoots with dimorphic decussate scale leaves, without glands, facial leaves broad, lateral boat-shaped, only slightly touching each other at the base. Shoots up to 11 mm long and 2 mm wide.

M a t e r i a l . Leafy shoots (Monte Tondo MSF1546, MSF1547).

Cupressoconus Kilpper
Cupressoconus sp.

Pl. 1, Fig. 16

A seed cone in cross section, composed of peltate scales, densely disposed around the axis, 5 mm long and 4 mm wide,

it corresponds in size to *Chamaecyparis* Spach rather than *Cupressus* Linneaus. The scale surface is not visible which makes specific identification impossible (see also Kilpper 1968a, b, Mai and Velitzelos 1997).

Material. Seed cone (Monte Tondo MSF1536).

Cupressus Linnaeus
Cupressus rhenana (Kilpper) Mai et Velitzelos

Pl. 1, Fig. 17; Pl. 2, Fig. 1

Leafy shoot regularly alternately branched, up to 50 mm long, covered with ovate-rhomboidal, acuminate, homomorphic decussate scale-like leaves not exceeded 1 mm in length. Orbiculate seed cone is 7 mm in diameter and composed of 8 decussate cone scales. Similar foliage and seed cone have been found at the late Miocene site Vegora, Greece (Kvaček et al. 2002). Furthermore, even if the occurrence of *Cupressus* cf. *sempervirens* Linnaeus indicated by Kovar-Eder et al. (2006) from the late Messinian site of Scipione Ponte (northern Italy) is referred to cones, these are associated with so far undescribed leafy shoots which are identical to those of Monte Tondo. We also revise here the material from Scipione Ponte (Cenofita Collection, University of Turin, Nr. CCN1470) as *Cupressus rhenana*, because the use of this fossil-species name is preferable in the absence of definite evidence proving that the fossils correspond in all characters to the modern species *Cupressus sempervirens*, and not to other closely related species .

Material. Leafy shoots (Monte Tondo MSF1551, MSF1552, MSF1553, MSF1554, MSF1556) and seed cone (Tossignano MSF1555).

Tetraclinis Masters
Tetraclinis salicornioides (Unger) Kvaček

Pl. 2, Fig. 2–3

Short branch consisting of cladode-like flattened segments (cladodium) of fused flat decussate leaves, up to 17 mm long, leaf base truncate to rounded, apex obtuse with terminal and two lateral incisions, towards apex gradually broadening, 4 fused in a pseudowhorl, innervating with distinct midrib and two lateral thin veins. One seed cone with 4 verticillate unequal scales orbiculate in outline 10 mm in diameter. This record is clearly different from xeromorphic *T. brachyodon* (Brongniart) Mai et Walther in the flat leafy segments (Teodoridis et al. 2015 – this volume).

Material. Foliage (Monte Tondo MSF1983, MSF1984, MSF1985, MSF1986; Tossignano MSF234) and cone (Monte Tondo MSF1987).

Basal angiosperms
Magnoliaceae Jussieu

Magnolia Linnaeus
cf. *Magnolia liblarensis* (Kräusel et Weyland) Kvaček

Pl. 2, Fig. 4–7

Leaves simple, lamina lanceolate or elliptic to ovate, up to 120 mm long and 45 mm wide, base widely cuneate to cuneate, narrowing into fragmentary petiole, apex acuminate and blunt, margin entire, venation brochidodromous with strong midrib and thinner, straight secondary veins looping by margin. Intersecondaries parallel, tertiary veins perpendicular, straight or slightly sinuous, often forked, venation of the higher orders regular polygonal reticulate, areolation well developed, 4-sided, veinlets lacking.

The leaves are morphologically similar to the anatomically characterized leaves of *Magnolia liblarensis* from Meleto and Arjuzanx (Fischer and Butzman 2000, pl. 19, figs 2–5; Kvaček et al. 2011). However we can not totally exclude also an affinity to the family Lauraceae. This studied plant material from Tossignano and Monte Tondo was preliminarily assigned to *Leguminosites hradekensis* (Knobloch et Kvaček) Kvaček et Teodoridis by Sami and Teodoridis (2013) and Sami et al. (2014).

Material. Leaf impressions (Monte Tondo MSF1756, MSF1757, MSF1758, MSF1759, MSF1760, MSF1761, MSF1762, MSF1763, MSF1764, MSF1765, MSF1766, MSF1767, MSF1768, MSF1769, MSF1770, MSF1771, MSF1772, MSF1773, MSF1774, MSF1775, MSF1776, MSF1777, MSF1778, MSF1779, MSF1780, MSF1781, MSF1782, MSF1783, MSF1784, MSF1785, MSF1786, MSF1787, MSF1788, MSF1789, MSF1790, MSF1791, MSF1792, MSF1793, MSF1794, MSF1795, MSF1796, MSF1797, MSF1798, MSF1799, MSF1800, MSF1801, MSF1802, MSF1803, MSF1804, MSF1805, MSF1806, MSF1807, MSF1808, MSF1809, MSF1810, MSF1811, MSF1812, MSF1813, MSF1814, MSF1815, MSF1816, MSF1817, MSF1818, MSF1819, MSF1820, MSF1821, MSF1822, MSF1823, MSF1824, MSF1825, MSF1826; M. D. IMG_4653, M. D. IMG_4657, M. D. IMG_4658, M. D. IMG_4660; Tossignano MSF220, MSF48, MSF298, MSF46a).

Lauraceae Jussieu

Ocotea Aublet
Ocotea heerii (Gaudin) Takhtajan

Pl. 2, Fig. 8–12

Leaves simple, often petiolate, lamina elliptic to widely elliptic, up to 92 mm long and 45 mm wide, base cuneate, apex acuminate and blunt, margin entire, venation brochidodromous, midrib strong and moderate, lowermost pair of secondary veins more distinct, higher pairs thinner, straight, looping by margin, alternate, distinct ovoid glands, up 2 mm long, in axils of some secondaries, tertiary veins perpendicular, straight to sinuous, rarely forked, venation of the higher orders regular polygonal reticulate, areolation well developed, 3- or 4-sided, veinlets probably lacking.

This leaf morphotaxon is sometimes synonymized with *Ocotea hradekensis* (Kvaček et Bůžek) Kvaček mainly due to the presence of glands (see Fischer and Butzman 2000, Teodoridis and Gregor 2001).

Material. Leaf impressions (Monte Tondo MSF351, MSF1561, MSF1563, MSF1837, MSF1838, MSF1839, MSF1840, MSF1841).

Daphnogene Unger
Daphnogene polymorpha (A. Braun) Ettingshausen

Pl. 2, Fig. 13–14

Text-fig. 3. CA climate charts for the Monte Tondo and Tossignano floras, showing climatic ranges of the Nearest Living Relatives of the fossil taxa with respect to MAT. Right-hand positoned large bold figures and shaded areas in each case indicate the Coexistence Interval, with the number of overlapping taxa being at a maximum.

Leaves simple, petiolate, lamina elliptic to widely elliptic, rarely obovate, up to 72 mm long and 50 mm wide, base rarely slightly asymmetric widely cuneate to cuneate, apex acuminate to shortly acuminate and blunt, margin entire, venation suprabasal acrodromous, midrib strong, moderate, straight or slightly curved in apical part, lateral veins thinner, alternate or opposite running along margin, usually connecting secondaries at 2/3 of the blade length, secondary veins thinner, alternate, curved and looping by margin or straight to forked between midrib and lateral veins, tertiary

veins alternate perpendicular, straight to sinuous, often forked, venation of the higher orders regular polygonal reticulate, areolation well developed, 3- to 4-sided, veinlets lacking.

This sub-triveined fossil species is widely spread in the Miocene of Europe and has also been assigned to the genus *Cinnamomum* on an account of more complete specimens from Oehningen (see in detail Holý et al. 2012) and the closest affinity with extant *Cinnamomum camphora* (Linnaeus) J. Presl.

M a t e r i a l. Leaf impressions (Monte Tondo MSF1557, MSF1558, MSF1559, MSF1560, MSF1562, MSF1564, MSF1565, MSF1566, MSF1567, MSF1568, MSF1569, MSF1570, MSF1571, MSF1572, MSF1573, MSF1574, MSF1575, MSF1576, MSF1577, MSF1578, MSF1579, MSF1580, MSF1581, MSF1582, MSF1583, MSF1584, MSF1585, MSF1586, MSF1587, MSF1588; Tossignano MSF34, MSF43, MSF311, MSF312, MSF608, MSF609).

Laurophyllum Goeppert
cf. *Laurophyllum pseudoprinceps* Weyland et Kilpper

Pl. 2, Fig. 15–16; Pl. 3, Fig. 1–2

Leaves simple, petiolate, lamina elliptic to ovate, up to 125 mm long and 55 mm wide, base cuneate, decurrent into up to 15 mm long petiole, apex acuminate and blunt, margin entire, venation brochidodromous, midrib strong, moderate, straight or slightly curved in apical part, secondary veins thinner, straight, looping by margin (slightly stronger lower secondaries), alternate, originating at 30–50°, tertiary veins perpendicular, straight to sinuous, venation of the higher orders regular polygonal reticulate, areolation well developed, 4-sided, veinlets not visible.

The determinations are based merely on similarities in gross morphology, similarly as in the case of the flora of Meleto and Arjuzanx (Fischer and Butzman 2000, Kvaček et al. 2011). However without anatomical structure the identification of the leaves must remain doubtful and may also belong to taxa of the Magnoliaceae and Nyssaceae families.

M a t e r i a l. Leaf impressions (Monte Tondo MSF1693, MSF1696, MSF1698; Tossignano MSF51).

Laurophyllum sp. 1

Pl. 3, Fig. 3–6

Large lauroid elliptic to ovate leaves with entire margin and brochidodromous venation of the same type as the above described taxon, can not be identifiable to the species level without abaxial epidermal structure being known. Similarly the affinity to Lauraceae is not guaranted and the studied leaves may belongs to other families e.g., Magnoliaceae, Nyssaceae. Due to the extreme leaf size exceeded a length of 220 mm, they are treated separately.

M a t e r i a l. Leaf impressions (Monte Tondo MSF1619, MSF1620, MSF1621, MSF1622, MSF1623, MSF1624, MSF1625, MSF1626, MSF1627, MSF1628, MSF1629, MSF1630, MSF1631, MSF1632, MSF1633, MSF1634, MSF1636, MSF1640, MSF1641, MSF1642, MSF1643, MSF1644, MSF1645, MSF1646, MSF1647, MSF1648, MSF1649, MSF1650, MSF1651; Tossignano MSF14, MSF25, MSF33, MSF39, MSF40, MSF46, MSF54, MSF85, MSF271, MSF273, MSF275, MSF276, MSF277, MSF 278, MSF288, MSF290, MSF294, MSF299, MSF323, MSF301, MSF303, MSF304, MSF305, MSF308, MSF309, MSF314, MSF319, MSF343, MSF348, IMG_4655, IMG_4664, IMG_4677).

Laurophyllum sp. 2

Pl. 3, Fig. 7–8; Pl. 4, Fig. 1

Middle sized lauroid leaves of the same morphological structure as *Laurophyllum* sp. 1 are not identifiable without abaxial epidermis. Similarly the affinity to Lauraceae is not clear.

M a t e r i a l. Leaf impressions (Monte Tondo MSF1652, MSF1653, MSF1654, MSF1655, MSF1656, MSF1657, MSF1658, MSF1659, MSF1660, MSF1661, MSF1662, MSF1663, MSF1664, MSF1665, MSF1666, MSF1667, MSF1668, MSF1669, MSF1670, MSF1671, MSF1672, MSF1673, MSF1674, MSF1675, MSF1676, MSF1677, MSF1678, MSF1679, MSF1680, MSF1681, MSF1682, MSF1683, MSF1684, MSF1685, MSF1686, MSF1687, MSF1688, MSF1689, MSF1690, MSF1691, MSF1692; Tossignano MSF289, MSF307, MSF345, M. D. IMG_4661, M. D. IMG_4666, M. D. IMG_4673, M. D. IMG_4676).

Monocotyledonae de Candolle
Potamogetonaceae Berchtold et J. Presl

Potamogeton Linnaeus
Potamogeton sp.

Pl. 4, Fig. 2–3

Leaves elliptic to ovate up to 110 mm long and 40 mm wide, apex attenuate, base widely cuneate to rounded, often asymmetrical, margin entire, venation parallel consisting of thicker veins interspaced at a distance of 0.5 mm by thinner lower-order lateral veins.

The recovered elliptical leaves of a *Potamogeton* species showing parallel venation, are comparable with some broad-leaved fossil species e.g., *P. martinianus* Sitár (Sitár 1969, Kovar-Eder 1992).

M a t e r i a l. Leaf impressions (Monte Tondo MSF1895, MSF1896, MSF1898, MSF1899, MSF1900; Tossignano MSF40, MSF41, MSF338, MSF1897, MSF1901).

Poaceae Barnhart
Bambusoideae Luerssen

Bambusa Linnaeus
Bambusa sp.

Pl. 4, Fig. 4–5

Leaves lanceolate to elliptic up to 95 mm in length and 12 mm wide, apex acute to shortly attenuate, base cuneate narrowing to short petiole (up to 5 mm), margin entire, venation acrodromous with thicker midrib and 2 to 3 lateral pairs of thick primary veins, interspaced at a distance of ca.

1 mm by parallel thinner lower-order lateral veins, originated from base of the midrib, venation of higher orders not preserved.

The impressions at hand are similar to leaves identified as *Bambusa lugdunensis* Saporta from the Neogene deposits in Europe (e.g., Grangeon 1958, Martinetto 2003, Worobiec 2003).

Material. Foliage impressions (Monte Tondo MSF1526; Tossignano MSF337, MSF339, MSF614).

Poaceae vel Cyperaceae gen. et sp. indet.

Strap-like unidentifiable monocot foliage.

Material. Foliage impressions (Monte Tondo MSF1886, MSF1887, MSF1888, MSF1890, MSF1891, MSF1892, MSF1893; Tossignano MSF46, MSF49, MSF301, MSF336, MSF342, MSF1889).

Eudicots

Berberidaceae Jussieu

Berberis Linnaeus

Berberis cf. *teutonica* (Unger) Kovar-Eder et Kvaček

Pl. 4, Fig. 6–7

Incomplete obovate leaves, 35 and 30 mm long, 16 and 18 mm wide, base cuneate, apex obtuse, margin almost entire, fine acute teeth in upper part, venation semi-craspedodromous with strong, moderate midrib and thinner, straight secondary veins looping by margin, originating at 20–40°, rarely single intersecondaries parallel to secondaries, tertiary veins perpendicular, straight to slightly sinuous, rarely forked, venation of the higher orders regular polygonal reticulate, areolation well developed, 4-sided, veinlets lacking.

Obovate, almost entire-margined leaves showing large loops of sub-basal secondary veins clearly correspond to the morphological characteristic of *Berberis*. They apparently differ from the common conspicuously dentate *Berberis berberidifolia* (Heer) Palamarev et Petkova see also Kovar-Eder et al. (2004).

Material. Leaf impressions (Monte Tondo MSF1527, MSF1528).

Platanaceae Lestiboudois

Platanus Linnaeus

Platanus leucophylla (Unger) Knobloch

Pl. 4, Fig. 10–14

Leaves long petiolate, palmately sub 3-lobed, rarely non-lobed, lamina broadly ovate, 40 to 95 mm long and 20 to 125 mm wide, medial lobe triangular to widely triangular, lateral lobes absent or triangular, apices acute, base cuneate to widely cuneate, petiole up to 32 mm long and 3 mm wide; margin irregularly coarsely simple serrate, at leaf base often entire, teeth obtuse to acute, venation basal actinodromous, 3 to 5 primary veins, straight, moderately thick, secondary veins thinner, alternate, straight, originating at angles of 30–40°, tertiary veins alternate to opposite percurrent, straight to sinuous, venation of the higher orders regular polygonal reticulate, areolation well developed, 3- to 4-sided, veinlets not preserved.

Both palmately lobed and simple leaves are present. This fossil species is widely distributed in the European late Miocene sites, e.g., Knobloch (1969) as *Platanus platanifolia* (Ettingshausen) Knobloch (Fischer and Butzman 2000, Kvaček et al. 2002, Kovar-Eder et al. 2006).

Material. Leaf impressions (Monte Tondo MSF1872, MSF1873, MSF1874, MSF1875, MSF1876, MSF1877, MSF1878, MSF1879, MSF1880, MSF1881, MSF1882, MSF1885; Tossignano MSF31, MSF086, MSF261, MSF262, MSF266, MSF267).

Altingiaceae Horaninow

Liquidambar Linnaeus

Liquidambar europaea A. Braun / cf. *L. magniloculata* Czeczott et Skirgiełło

Pl. 4, Fig. 8–9, 13; Pl. 5, Fig. 1

Incomplete leaf and fragment, palmately trilobed or pentalobed, 35 and 115 mm long, 30 and 60 mm wide, lobes oblong to ovate, base widely cuneate or cordate, apex not preserved, probably obtuse, margin regularly crenulated to serrate, teeth glandular and acute, venation basal actinodromous, 3 or 5 primary veins strong and moderate, at angles of 45–50°, secondaries thinner, straight or slightly curved, alternate, looping near margin, tertiary veins perpendicular, slightly sinuous, venation of the higher orders not preserved. Globular to oval infructescences ca. 8 to 15 mm in diameter, relatively deep faveolate locules are visible.

Palmate leaves with crenulate margin fit well into the species concept suggested by Knobloch (1969). The associated infructescences compare well to specimens assigned as *L. magniloculata* Czeczott et Skirgiełło (Fischer and Butzmann 2000), but the preservation is poor, therefore an affinity to *Platanus* can not be ruled out.

Material. Leaf impressions (Monte Tondo MSF1753, MSF1754, MSF1755) and globular infructescences (Monte Tondo MSF1757, MSF1758; Tossignano MSF611).

cf. *Liquidambar* sp.

Pl. 4, Fig. 14

Fragment of marginal part of leaf lamina 25 mm long and 20 mm wide, apex and base not preserved, margin finely crenulate, teeth fine glandular, venation well preserved, veins looping by margin, thin vein innervating sinuses of teeth, venation of the higher orders regular polygonal reticulate, areolation well developed, 4-sided, veinlets lacking or not preserved. The crenulate leaf margin resembles the above described taxon, but the innervation of the teeth may indicate an affinity to other taxa/family e.g., Oleaceae, Rosaceae.

Material. Leaf fragment (Monte Tondo MSF1756).

Leguminosae Jussieu

Leaflets of legumes are common at both studied sites but difficult to distinguish into more natural species. The following survey stresses mainly size differences and general

shape of the leaflets. The important trait, short petiolule, helps to differentiate such foliage, previously usually assigned to the carpologicalgenus *Leguminosites* Bowerbank, from other angiosperms with similar blade forms.

Leguminosae gen. et sp. indet. 1

Pl. 5, Fig. 2–5

Leaflets shortly petiolulate, middle sized to relatively big, lamina elliptic to ovate, 45 to 110 mm long and 20 to 55 mm wide, base rounded to widely cuneate, petiolule short, apex attenuate to obtuse, margin entire, venation brochidodromous, midrib strong, moderate, straight, secondary veins numerous, thinner, straight or curved, looping, alternate, at angles of 40–60°, intersecondaries rarely obvious, thinner, parallel with secondaries, tertiary veins alternate percurrent, curved to sinuous, venation of the higher orders regular polygonal reticulate, areolation well developed, areoles 3- or 4-sided, veinlets lacking.

The bigger leaflets are morphologically similar to the leaf material described as cf. *Magnolia liblarensis*, cf. *Laurophyllum pseudoprinceps* and *Laurophyllum* sp. 2.

Material. Leaflet impressions (Monte Tondo MSF1705; MSF1706, MSF1707, MSF1708, MSF1709, MSF1710, MSF1711, MSF1712, MSF1713, MSF1714, MSF1715, MSF1716, MSF1717, MSF1718, MSF1719, MSF1720, MSF1721, MSF1722, MSF1723, MSF1724, MSF1725, MSF1726, MSF1727, MSF1728, MSF1729, MSF1730, MSF1731, MSF1732; Tossignano MSF284, MSF300, MSF306, MSF320, MSF322, MSF327, MSF330, MSF331, MSF332, MSF333,MSF335, MSF346, MSF610, MSF616, MSF618, MSF619, MSF74, M. D. IMG_4671, M. D. IMG_4662, M. D. IMG_4665, M. D. IMG_4669).

Leguminosae gen. et sp. indet. 2

Pl. 5, Fig. 6–9

Leaflets shortly petiolulate, relatively small, lamina elliptic to ovate or rarely obovate, 15 to 60 mm long and 8 to 20 mm wide, base rounded to widely cuneate, apex obtuse to emarginated, rarely shortly attenuate, margin entire, venation brochidodromous, midrib strong, moderate, straight, secondary veins numerous, thinner, straight or curved, rarely forked by margin, looping, alternate or subopposite, at angles of 40–60°, intersecondaries often obvious, thinner, parallel with secondaries, tertiary veins alternate percurrent, curved to sinuous, venation of the higher orders regular polygonal reticulate, areolation well developed, areoles 3- or 4-sided, veinlets lacking.

Material. Leaflet impressions (Monte Tondo MSF1732, MSF1733, MSF1734, MSF1735, MSF1736, MSF1737, MSF1738; Tossignano MSF221, MSF321, MSF328, MSF621, M. D. IMG_4650).

Leguminosae gen. et sp. indet. 3

Pl. 5, Fig. 10–12

Leaflets shortly petiolulate, middle sized, lamina widely ovate to widely elliptic, 35 to 83 mm long and 15 to 65 mm wide, base rounded to widely cuneate, petiolule short and thick, apex obtuse, margin entire, venation brochidodromous, midrib strong, moderate, straight, secondary veins numerous, thinner, straight or curved, looping, alternate, at angles of 40–80°, intersecondaries often obvious, thinner, parallel with secondaries, tertiary veins alternate percurrent, curved to sinuous, venation of the higher orders regular polygonal reticulate, areolation well developed, areoles 3- or 4-sided, veinlets lacking.

Material. Leaflet impressions (Monte Tondo MSF1739, MSF1740, MSF1741, MSF1742, MSF1743, MSF1744, MSF1745, MSF1746, MSF1747, MSF1748, MSF1749).

Leguminosae gen. et sp. indet. 4

Pl. 6, Fig. 1–2

Leaflets shortly petiolulate, leptophyllous, lamina elliptic to slightly obovate, 4 to 15 mm long and 3 to 6 mm wide, base asymmetric widely cuneate, petiolule short, relatively thick (0.5 mm long), apex obtuse to emarginated, margin entire, venation brochidodromous, midrib strong, moderate, straight, secondary veins numerous, thinner, straight or slightly curved, looping, alternate to subopposite, at angles of 40–60°, tertiary veins alternate percurrent, curved to sinuous, often forked, venation of the higher orders not preserved.

Material. Leaflet impressions (Monte Tondo MSF1750, MSF1751; Tossignano MSF1752).

Rosaceae Jussieu
***Rosa* Linnaeus**
***Rosa* sp.**

Pl. 6, Fig. 3–4

Leaflets shortly petiolulate, lamina elliptic to ovate, 12 and 20 mm long, 7 and 10 mm wide, base rounded, apex obtuse, margin simply serrate, teeth rectangular, close, acute to blunt, sinus angular, venation semicraspedodromous, midrib strong, moderate, straight or curved, secondary veins thinner, straight, looping by the margin, alternate, at angles of 40–60°, tertiary veins alternate to opposite percurrent, straight to sinuous, rarely forked, venation of the higher orders regular polygonal reticulate, areolation well developed, areoles 3- or 4-sided, veinlets not visible.

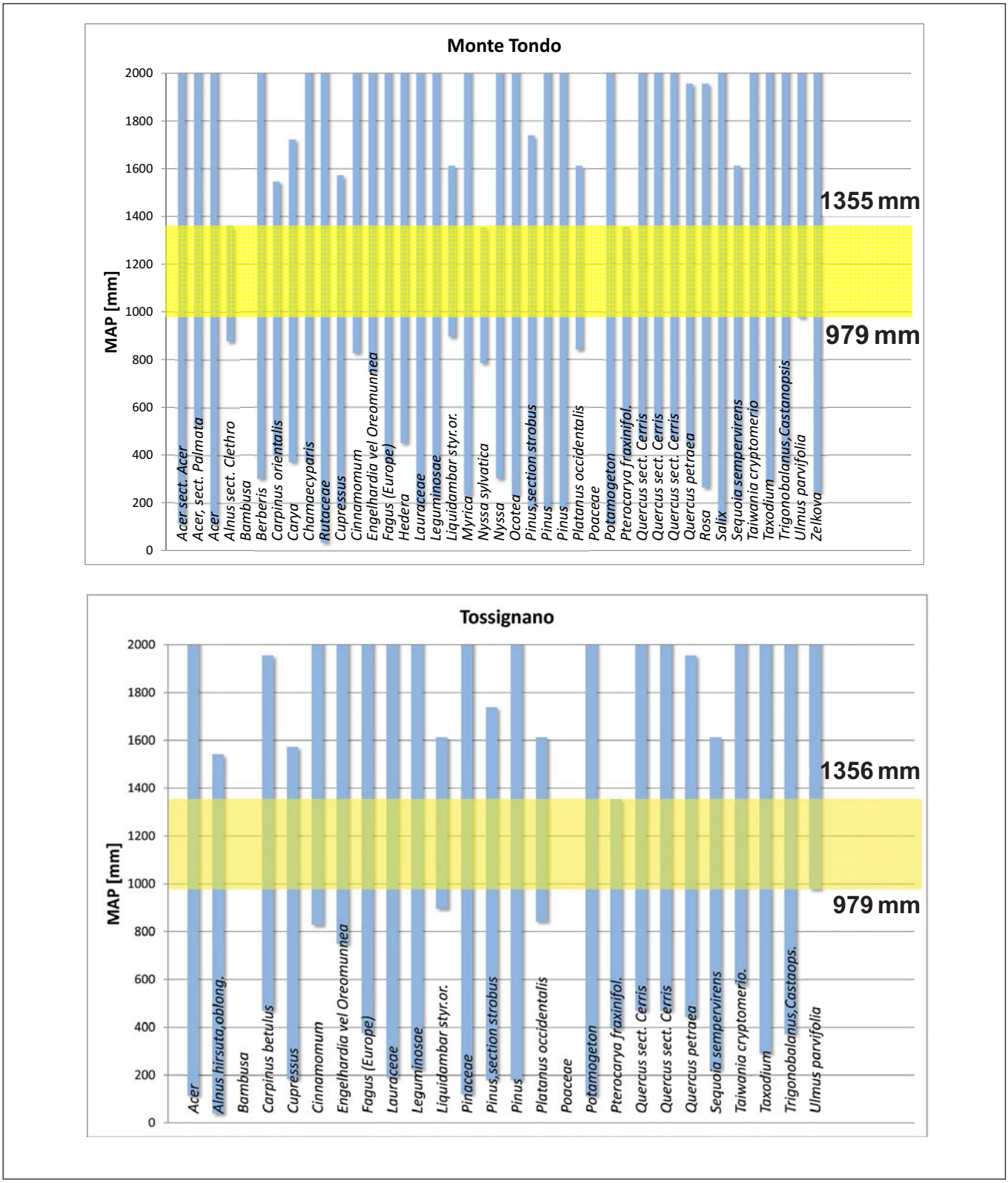
The recovered leaflets with the serrate margin obviously belong to *Rosa* and match various fossil species, such as *R. europaea* Kvaček et Hurník (Kvaček and Hurník 2000, Bůžek 1971, as *Rosa bohemica* Engelhardt).

Material. Isolated leaflet impressions (Monte Tondo MSF1947, MSF1948).

Rosaceae gen. et sp. indet. 1

Pl. 6, Fig. 5

Leaflet lanceolate, 90 mm long and 17 mm wide, base slightly asymmetric widely cuneate, apex incomplete probably acute or obtuse, margin entire in the basal part, finely serrate, teeth close, acute, sinus angular, venation



Text-fig. 4. CA climate charts for the Monte Tondo and Tossignano floras, showing climatic ranges of the Nearest Living Relatives of the fossil taxa with respect to MAP. For legend see Text-fig. 3.

semicraspedodromous, midrib strong, moderate, curved, secondary veins thinner, curved, looping by the margin, alternate, at angles of 40–60°, tertiary veins alternate to opposite percurrent, straight to sinuous, venation of the higher orders regular polygonal reticulate, areolation well developed, areoles 3- or 4-sided, veinlets not visiable. A falcate leaflet finely serrate is assigned to the Rosaceae with hesitation. An affinity to the Juglandaceae, e.g., *Pterocarya* could also be possible.

M a t e r i a l . Leaflet impression (Monte Tondo MSF1949, MSF1950).

Rosaceae gen. et sp. indet. 2

Pl. 6, Fig. 6

Incomplete leaf obovate in outline, 16 mm long and 8 mm wide, base cuneate, apex obtuse, margin coarsely serrate, teeth acute, venation semicrapedodromous, midrib moderate, curved, secondary veins thinner, straight, alternate to subopposite, at angles of 30–40°, looping by the margin, principal veins innervate in sinus, tertiary veins alternate to opposite percurrent, straight to sinuous, venation of the higher orders regular polygonal reticulate, areolation well developed, areoles 3- or 4-sided, veinlets probably lacking.

The leaf could also be assigned to the Rosaceae but with hesitation, however the innervetion of teeth sinuses may also indicate an affinity to the Oleaceae (*Fraxinus* Linnaeus).

M a t e r i a l . Leaf impression (Monte Tondo MSF1907).

***Pyracantha* M. Roemer**
cf. *Pyracantha* sp.

Pl. 6, Fig. 7–8

Leaves elliptic to rarely ovate, petiolate, 25 to 58 mm long 7 and 15 mm wide, base cuneate to widely cuneate, apex obtuse to acute, margin coarsely serrate, teeth, close, blunt, rarely acute, often regular, sinus angular, venation semicraspedodromous, midrib strong, straight, moderate, secondary veins steep, thinner, straight, looping by the margin, alternate, rarely forked, tertiary veins alternate to opposite percurrent, straight to sinuous, venation of the higher orders regular polygonal reticulate, areolation well developed, areoles 3- or 4-sided, veinlets poorly preserved, probably lacking.

The leaves characterized by moderately steep secondary semicraspedodromous venation are similar to the evergreen foliage of *Pyracantha*, a native shrub from southern Europe to central China. It also resembles the fossil species *P. kraeuselii* Walther (Mai and Walther 1978) known from the Oligocene of Saxony.

M a t e r i a l . Leaf impressions (Monte Tondo MSF1908, MSF1909, MSF1910, MSF1911, MSF1912, MSF1913, MSF1914, MSF1915, MSF1916, MSF1917, MSF1918).

***Photinia* Lindley**
cf. *Photinia* sp.

Pl. 8, Fig. 6–8; Pl. 12, Fig. 14

The figured elliptic to obovate finely serrulate leaves with semicraspedodromous venation differ from the above characterized fossils only by their bigger size (up to 120 mm long and 45 mm wide) and more regular campto-dromous-semicraspedodromous dense secondary veins. The leaves can be more clearly compared with leaves of *Photinia,* a shrub native to the Himalayas, SE Asia and N America (partly separated as *Heteromeles arbutifolia* (Lindley) M. Roemer) rather than with *Pyracantha*. Reliably determined fossil records from the European Neogene have not yet been published. The morphological variability of the figured leaves is great, therefore we can not be sure that it belongs to one natural taxon.

M a t e r i a l . Leaf impressions (Monte Tondo MSF1842, MSF1843, MSF1844, MSF1845, MSF1846).

Rhamnaceae Jussieu

***Berchemia* Necker ex de Candolle**
cf. *Berchemia* sp.

Pl. 6, Fig. 9

Leaf elliptic, 57 mm long and 19 mm wide, base widely cuneate, apex incomplete probably shortly attenuate and blunt, margin entire, venation eucamptodromous, midrib strong, straight, moderate, secondary veins thinner, straight, looping by the margin, alternate, tertiary veins opposite to subopposite percurrent, straight to sinuous, venation of the higher orders regular polygonal reticulate, areolation poorly preserved, areoles 3- or 4-sided.

The petiolate leaf showing a characteristic rhamnoid eucamptodromous venation is similar to those of the common fossil-species *Berchemia multinervis* (A. Braun) Heer (see Bůžek 1971).

M a t e r i a l . Leaf impression (Monte Tondo MSF1529).

Ulmaceae Mirbel

***Ulmus* Linnaeus**
***Ulmus plurinervia* Unger**

Pl. 6, Fig. 10, 12; Pl. 10, Fig. 3

Leaves simple, shortly petiolate, lamina narrow ovate to ovate or obovate, 19 to 56 mm long and 14 to 44 mm wide, base asymmetric widely cuneate to rounded, apex acuminate to acute, margin double serrate, primary teeth rectangular, secondary teeth usually finer, venation craspedodromous, midrib strong, moderate, curved, secondary veins thinner, straight, distinct, numerous, often forked, alternate to opposite, at an angle of 30–50°, tertiary veins alternate percurrent, straight to sinuous, venation of the higher orders regular polygonal reticulate, areolation well developed, areoles 3- or 4-sided.

Strongly asymmetrical leaves with forked craspedo-dromous venation and dense secondary veins are of the same type as those recovered at Parschlug (Kovar-Eder et al. 2004).

M a t e r i a l . Leaf impressions (Monte Tondo MSF1533, MSF1534, MSF1998, MSF1999, MSF2000, MSF2001, MSF2002, MSF2003; Tossignano MSF32).

***Ulmus* sp. (fruit)**

Pl. 6, Fig. 11

Obovate fruits up to 26 mm long show partly wrinkled surface with a elliptic seed in the centre (4 mm in diameter) corresponding to those of the genus *Ulmus*.

M a t e r i a l . Fruits (Monte Tondo MSF708, MSF710).

***Zelkova* Spach**
***Zelkova zelkovifolia* (Unger) Bůžek et Kotlaba**

Pl. 7, Fig. 1–2

Leaves simple, shortly petiolate, elliptic to ovate, asymmetrical, 24 to 54 mm long and 14 to 34 mm wide, base widely cuneate to slightly cordate, apex shortly acute to acuminate, margin coarsely simple dentate to serrate, venation craspedodromous, midrib strong, moderate, straight, secondary veins distinct, alternate, straight or curved, at angles of 40–60°, tertiary veins straight, thin, often alternate percurrent, venation of the higher orders regular polygonal reticulate, areolation well developed, areoles 3- or 4-sided, veinlets not preserved.

Coarsely simple dentate-serrate leaves with craspedodromous secondary veins more widely spaced than in *Ulmus* are typical traits of *Zelkova zelkovifolia,* widely distributed in the Oligocene and Neogene of Europe (e.g., Kvaček et al. 2011).

M a t e r i a l . Leaf impressions (Monte Tondo MSF2007, MSF2008, MSF2009, MSF2010, MSF2011, MSF2012).

Fagaceae Dumortier

***Quercus* Linnaeus**
***Quercus kubinyii* (Kovats ex Ettingshausen) Czeczott vel *Q. drymeja* Unger**

Pl. 7, Fig. 4–5

Leaves elliptic to ovate, 48 to 110 mm long and 22 to 62 mm wide, apex acute to acuminate, base widely cuneate or rounded, margin simple serrate, teeth acute to spiny, rarely close, sinuses rounded, venation craspedodromous, midrib strong, moderately, straight, secondary veins thin, straight, relatively numerous, alternate, at angles of 30–50°, tertiary veins distinct, alternate percurrent, straight to convex, rarely forked, venation of higher orders regular, polygonal reticulate; areolation well developed or moderately developed, 3- or 4-sided.

The oak foliage assigned to this entity deviates from the standard leaf forms of the indicated fossil species, partly by the finer dentation and partly by the form of the blade. It is difficult to differentiate between *Castanea* Miller and *Quercus* and therefore the taxon was often published as belonging to *Castanea* (Knobloch and Kvaček 1976).

M a t e r i a l . Leaf impressions (Monte Tondo MSF1922, MSF1923, MSF1924; Tossignano MSF222, MSF250, MSF253, MSF255).

***Quercus mediterranea* Unger**

Pl. 7, Fig. 7–9

Leaves obovate to widely elliptic or ovate, 24 to 60 mm long and 12 to 36 mm wide, apex acute to obtuse, base slightly asymmetric, rounded with fragmentary petiole up to 5 mm long, margin simple serrate, teeth acute, sinuses rounded, venation craspedodromous, midrib strong, moderately often curved, secondary veins thin, straight or curved, alternate, at angles of 30–50°, tertiary veins distinct, alternate percurrent, straight to convex, rarely forked, venation of higherorders regular, polygonal reticulate, areolation distinct or moderately developed, 3- or 4-sided.

Similar oak foliage has also been assigned to *Q. drymeja* Unger (e.g., Kvaček et al. 2002) but for more accurate determination of the fossil species additional epidermal characteristics are needed (Kvaček and Walther 2012).

M a t e r i a l . Leaf impressions (Monte Tondo MSF1925, MSF1926, MSF1927, MSF1929; Tossignano MSF223, MSF259).

***Quercus pseudocastanea* Goeppert**

Pl. 7, Fig. 10–12

Some leaf forms of this species, e.g., from Vegora (Kvaček et al. 2002), are clearly comparable with the figured specimens from Monte Tondo.

M a t e r i a l . Leaf impressions (Monte Tondo MSF1930, MSF1931, MSF1932, MSF1933, MSF1934, MSF1935, MSF1936, MSF1937, MSF1938, MSF1939, MSF1940, MSF1941, MSF1942, MSF1943).

***Quercus roburoides* Gaudin**

Pl. 8, Fig. 1–2

Leaves long petiolate, obovate, pinately lobed, 52 to 130 mm long and 25 to 65 mm wide, base rounded or cuneate to decurrent, apex slightly attenuate to obtuse, margin entire in basal part, coarsely simply dentate in the apical part, teeth obtuse to rounded, sinuses rounded, slightly opened to widely opened, venation simple craspedodromous, midrib strong, moderate, secondary veins thinner, alternate, straight to curved, tertiary veins alternate precurrent, sinuous to straight, venation of the higher orders regular polygonal reticulate, areolation well developed, 3- to 4-sided.

The figured leaves of roburoid oaks are characterized by the regular round-lobate margin and are typical of Miocene and Pliocene floras (see e.g., Kvaček et al. 2008). Unless characterized by epidermal anatomy they can easily be mistaken for the previous species as happened in the flora of Vegora (Kvaček et al. 2002, pl. 14, fig. 1, pl. 15, figs 1, 4).

M a t e r i a l . Leaf impressions (Monte Tondo MSF1944, MSF1945; Tossignano MSF35, MSF53, MSF252, MSF254, MSF256, M. D. IMG_4654).

***Quercus* sp. (fruit)**

Pl. 7, Fig. 3

Detached acorns without cupules rounded in shape, 15 and 19 mm in diameter, with distinct longitudinal striation on the upper surface certainly belong to *Quercus*, but cannot be assigned to any particular species of *Quercus* based on the foliage described above.

M a t e r i a l . Incomplete fruits (Monte Tondo MSF1919, MSF1920).

cf. *Quercus* sp. div.

Pl. 7, Fig. 6, 13

Leaves elliptic and obovate, 42 and 71 mm long, 30 to 42 mm wide, base slightly asymmetric rounded, apex incomplete shortly attenuate and obtuse, margin entire in basal part, irregularly, coarsely, simply dentate in the apical part, teeth acute and obtuse, sinuses rounded, venation simple

craspedodromous, midrib strong, moderate, secondary veins thinner, alternate or subopposite, straight to curved, tertiary veins alternate precurrent, sinuous to straight, venation of the higher orders regular polygonal reticulate, areolation well developed, 3- to 4-sided.

The incomplete preservation prevents exact identification of a part of the impressions, although the affinity to oaks is probable for both figured leaves.

Material. Leaf impressions (Monte Tondo MSF1921; Tossignano MSF257).

Trigonobalanopsis Kvaček et Walther
Trigonobalanopsis rhamnoides (Rossmässler) Kvaček et Walther

Pl. 8, Fig. 3, ?4, 5

Leaves petiolate, elliptic, 45 to 91 mm long and 17 to 51 mm wide, base cuneate to widely cuneate with short petiole, up to 7 mm long, apex acuminate and obtuse, margin entire, venation brochidodromous, midrib strong, moderate, straight, secondary veins thinner, distinct, straight or slightly curved, looping by margin, alternate, at angles of 30–60°, tertiary veins alternate to opposite percurrent, straight to sinuous, rarely forked, venation of the higher orders regular polygonal reticulate, areolation well developed, areoles 4-sided, veinlets not visible.

The typical leaf form and venation allow identification of this species, commonly occurring in the Messinian of Italy (e.g., Kovar-Eder et al. 2006), even without cuticle structure. Pliocene records of *Trigonobalanopsis* cupules in the Pliocene of Italy were reported by Bertoldi and Martinetto (1995), Basilici et al. (1997), Martinetto and Ravazzi (1997) and Fischer and Butzmann (2000). The above described leaf forms show wider variation in shape of leaf lamina, but fit well to the concept of this species (see Knobloch and Kvacek 1976, Fischer and Butzmann 2000, Kvacek et al. 2011).

Material. Leaf impressions (Monte Tondo MSF1989, MSF1990, MSF1991, MSF1992, MSF1993, MSF1994, MSF1995, MSF1996; Tossignano MSF347, MSF1997, M. D. IMG_4663).

Fagus Linnaeus
Fagus gussonii Massalongo emend. Knobloch et Velitzelos

Pl. 8, Fig. 9–12; Pl. 10, Fig. 4

Leaves elliptic to ovate, 47 to 110 mm long, 32 to 75 mm wide, base often asymmetric, rounded to widely cuneate with petiole up to 13 mm long, apex acute to attenuate, margin simply widely serrate, teeth regularly spaced, distinct, acute, venation simple craspedodromous, midrib straight, moderate, secondary veins straight, alternate, regularly spaced, tertiary veins straight to sinuous, alternate percurrent, venation of the higher orders regular polygonal reticulate, areolation well developed, 3- to 4-sided.

Such fossil foliage of beech has usually been assigned to *Fagus gussonii* based on the Neogene records from southern Europe (Kvaček et al. 2002, Denk 2004).

Material. Leaf impressions (Monte Tondo MSF1608, MSF1609, MSF1610, MSF1611, MSF1612, MSF1613, MSF1614, MSF1615, MSF1616, MSF1617; Tossignano MSF25, MSF47, MSF258, MSF1532).

Myricaceae Richard

Myrica Linnaeus
Myrica lignitum (Unger) Saporta

Pl. 9, Fig 1–3

Leaves simple, petiolate, elliptic, 33 to 50 mm long and 8 to 10 mm wide, base cuneate with fragmentary petiole, apex obtuse, margin entire, venation brochidodromous, midrib strong, moderate, straight or curved, secondary veins poorly preserved, thinner, looping by margin, alternate, at angles of 40–60°, tertiary veins alternate percurrent, straight to sinuous, venation of the higher orders not visible.

The figured lanceolate entire-margined leaves with long decurrent base are identifiable even without anatomical evidence as *Myrica lignitum*, a widely distributed element in the European late Palaeogene and Neogene (see Kovar-Eder et al. 2004). The dentate forms were not encountered in the studied material. The specimen figured in Pl. 9, Fig. 3 differs from standard leaves of *Myrica lignitum* in its denser venation and bluntly acute apex.

Material. Leaf impressions (Monte Tondo MSF1827, MSF1828, MSF1829).

Juglandaceae de Candolle ex Perleb

Engelhardia Leschenault ex Blume
Engelhardia (sect. *Palaeocarya*) *macroptera* (Brongniart) Unger

Pl. 9, Fig. 6

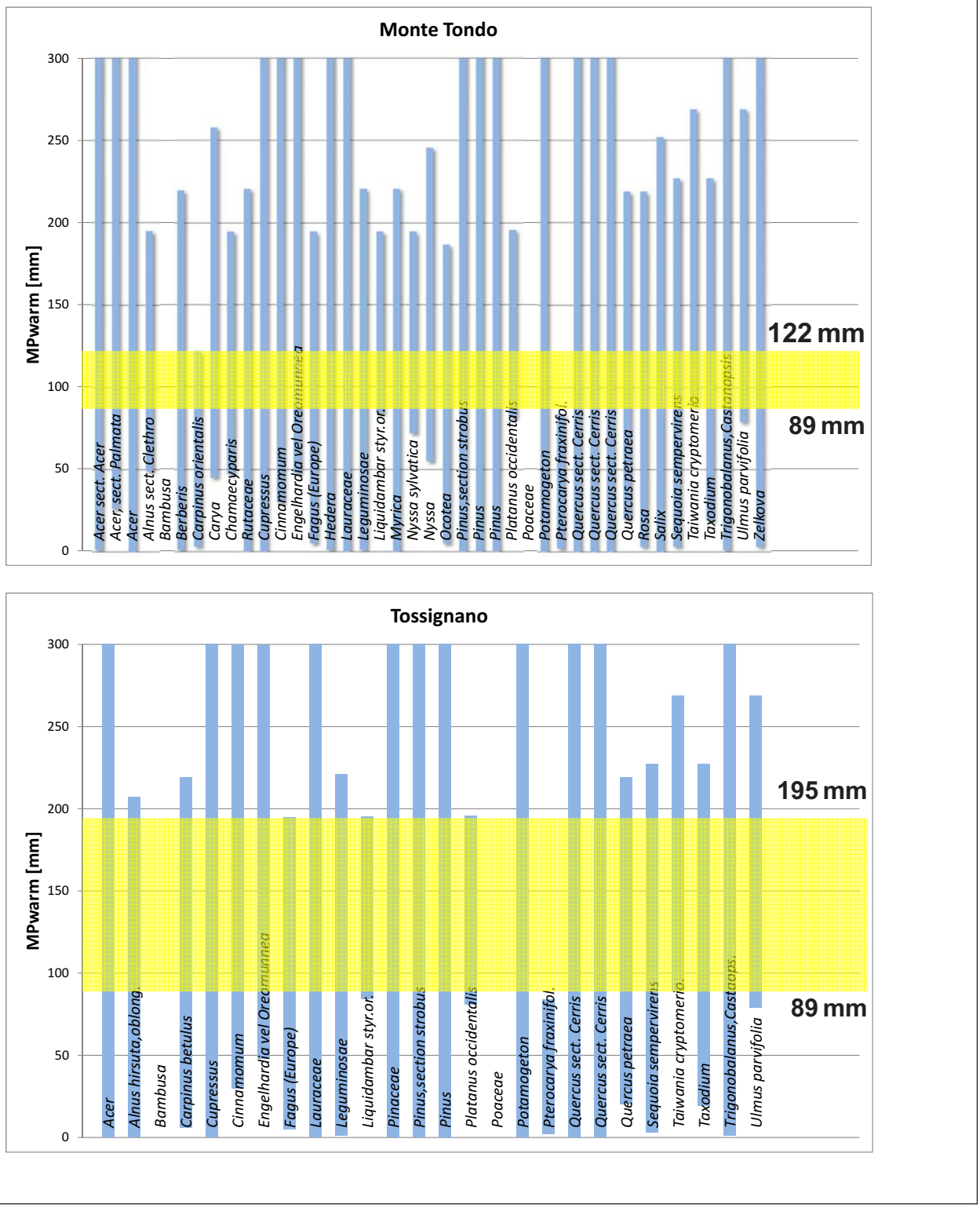
Fruits 21 to 35 mm long and 17 to 27 mm wide with characteristic involucres consisting of three main triveined lobes and one basal opposite, enveloping the nut (3 to 5 mm in diameter), typical traits of this fossil species (Mai in Jähnichen et al. 1977). They were recovered only rarely in the material at hand. They accompany the above foliage at most sites in the European Oligocene and Miocene. In Italy the involucres have been reported from Messinian (Bertini and Martinetto 2008) and Pliocene sites (Fischer and Butzmann 2000), as well as from a site of uncertain Pliocene or Pleistocene age.

Material. Some fruits (Monte Tondo MSF1605, MSF1606; Tossignano MSF38, MSF245, MSF246, MSF247, MSF623).

Pterocarya Kunth
Pterocarya paradisiaca (Unger) Iljinskaya

Pl. 9, Fig. 7–8

Incomplete leaflet, oblong 64 mm long and 45 mm wide, apex not preserved, base asymmetric, widely cuneate, margin simple serrate, venation semicraspedodromous, midrib distinct, moderately narrowed, secondary veins distinctly thinner, alternate or subopposite in basal part, originating at almost right angles, tertiary veins alternate, percurrent, straight to sinuous, venation of the higher orders regular polygonal reticulate, areolation well developed, 3- to 4-sided.



Text-fig. 5. CA climate charts for the Monte Tondo and Tossignano floras, showing climatic ranges of the Nearest Living Relatives of the fossil taxa with respect to MPwarm. For legend see Text-fig. 3.

Leaflets of *Pterocarya* are usually strongly asymmetrical, simple serrate. They can be reliably distinguished from those of *Carya* on account of the epidermal characteristics (Kvaček et al. 2008).

M a t e r i a l . Leaflets (Monte Tondo MSF1544; Tossignano MSF30).

Carya Nuttall
Carya sp.

Pl. 9, Fig. 9–11

Leaflet asymmetric, elliptic, 81 mm long and 26 mm wide, base widely cuneate to rounded, apex acuminate, margin regularly simple serrate, teeth acute, sinuses often

angular, venation craspedodromous (in apical part) to semicraspedodromous (in medial and basal parts), midrib strong, moderate, slightly curved, secondary veins distinct, alternate, numerous, curved towards the apex and margin, at angles of 60–70°, rarely forked, thin tertiary veins numerous, alternate percurrent, straight to curved, venation of the higher orders poorly preserved.

Leaflets of *Carya* are characterized by the forked ends of secondary veins and typical variation between craspedodromous and semicraspedodromous venation type. The natural affinities are best recognizable in fossil fruits (Mai 1981).

Material. Leaflet impression (Monte Tondo MSF1902, MSF1903).

Betulaceae Gray

***Betula* Linnaeus**
cf. *Betula* sp.

Pl. 9, Fig. 12

Leaf simple, ovate, 12 mm long and 11 mm wide, apex incomplete, probably acute to shortly acuminate, base slightly asymmetric cordate, margin irregularly double serrate, teeth relatively big, acute, sinus angular, venation craspedodromous, midrib straight, moderate, zig-zag in basal part, secondary veins subopposite in basal part and alternate, thinner, straight, regularly spaced, at angles of 35–50°, in 6 pairs, tertiary veins alternate percurrent, straight, often forked, venation of the higher orders regular polygonal reticulate, areolation well developed, 4-sided.

This rounded betuloid leaf is characterized by fan-like dense craspedodromous secondary veins and densely double serrate margin. We have not found any particular fossil species clearly identifiable with this specimen and cannot rule out other generic affinities.

Material. Leaf impression (Monte Tondo MSF1530).

***Alnus* Miller**
***Alnus cecropiifolia* (Ettingshausen) Berger**

Pl. 9, Fig. 13

Incomplete leaf widely elliptic, 55 mm long and 54 mm wide, apex and base not preserved, margin poorly preserved, irregularly simple serrate, teeth acute, sinus angular, venation simply craspedodromous, midrib straight, strong, secondaries alternate, thinner, regularly spaced, straight, tertiary veins poorly visible, alternate percurrent, straight to curved, venation of the higher orders not preserved.

This broad-leaved alder is a typical tree of swamps and riparian forests in the late Miocene of the Paratethys area (Knobloch 1969, Kvaček et al. 2002). In the Pliocene of Italy it has been found, associated with *Glyptostrobus* in deposits of swamp facies (Martinetto 1994, Martinetto and Farina 2005).

Material. Leaf impression (Tossignano MSF260).

***Alnus* cf. *menzelii* Raniecka-Bobrowska**

Pl. 9, Fig. 14

Incomplete simple leaf, widely elliptic, 67 mm long and 62 mm wide, apex not preserved, base rounded, margin irregularly simple serrate, teeth acute to spiny, sinus angular, venation simply craspedodromous, midrib straight, moderate, strong, secondaries alternate, thinner, at angles of 40–60°, curved, tertiary veins alternate to subopposite percurrent, straight or curved, venation of the higher orders regular polygonal reticulate, areolation well developed, 4-sided, veinlets lacking.

The leaf material is morphologically similar to *Alnus menzelii* and also *Alnus rotundata* Goeppert (Raniecka-Bobrowska 1954, Zastawniak and Walther 1998), which are commonly known from the European Oligocene and Neogene. An affinity to *Alnus ducalis* (Gaudin) Knobloch is also possible, however a typically deeply emarginate apex is not preserved (Knobloch 1969, Kvaček et al. 2002).

Material. Leaf fragment (Monte Tondo MSF1524, MSF1525).

***Carpinus* Linnaeus**
***Carpinus* cf. *betulus* Linnaeus**

Pl. 10, Fig. 1

Fruit with involucre 3-lobed, 32 mm long and 21 mm wide, base slightly asymmetric, rounded with fragmentary stalk up to 6 mm long, lobes oblong, medial larger than unequal lateral lobes, apices blunt, margin entire, occasionally with obvious isolated acute teeth on apical part of the medial lobe, nutlet ovate, base rounded, apex obtuse 6 mm long and 4 mm wide.

Fruits of the common hornbeam, called also the *Carpinus betulus* type, show tripartite entire-margined involucres. They are well distributed in the European Neogene (see e.g., Geissert 1987).

Material. Fruit impression (Tossignano MSF607).

***Carpinus* cf. *orientalis* Miller**

Pl. 10, Fig. 2

Incomplete fruit with involucre 3-lobed, 23 mm long and 17 mm wide, base slightly asymmetric, rounded with fragmentary stalk up to 8 mm long, lobes oblong, medial larger than unequal lateral lobes (only one preserved), apices not preserved probably blunt, margin entire, venation actinodromous, primary veins straight, secondaries thinner, straight, opposite, at angles of 80–90°, looping by margin, venation of the higher orders regular polygonal reticulate, areolation well developed, 4-sided, nutlet ovate, base rounded, apex acute and blunt, 6 mm long and 4 mm wide, longitudinal striation on upper surface.

The hornbeam involucres, similar to *C. orientalis* in the asymmetrical shape and one enlarged coarsely dentate side lobe, belong to another typical element of mesic vegetation of the European Cenozoic. It started to occur in the latest Eocene (Kvaček et al. 2014, pl. 4Q, R, as *C. mediomontana* Mai) and continues in several fossil species (Mai 1995) till the recent.

Material. Impression of fruit (Monte Tondo MSF1535).

Salicaceae Mirbel

***Salix* Linnaeus**
***Salix* sp.**

Pl. 9, Fig. 4–5; Pl. 10, Fig. 5–7

Leaves petiolate, narrow elliptic to ovate, 40 to 82 mm long and 9 to 11 mm wide, apex attenuate, base widely cuneate to rounded with incomplete petiole up to 4 mm long, margin entire in the basal part, regularly simply serrate, teeth acute to rounded, glandular, sinus angular, venation semicraspedodromous to eucamptodromous, midrib strong, straight, moderate, secondaries subopposite to alternate, distinctly thinner, numerous, curved, originating at acute angles, tertiary veins alternate to opposite percurrent, straight to convex or sinuous, marginal veinlets innervating teeth apices, venation of the higher orders regular polygonal reticulate, areolation well developed, 3- to 4-sided.

These narrow leaves undoubtedly belong to a willow. Similar morphotypes are usually assigned to *Salix lavateri* A. Braun typified by populations from the middle Miocene of the Oehningen area (e.g., Hantke 1954).The exact distinguishing traits have not been clarified so far, even in cases of anatomically preserved material (e.g., Kvaček et al. 2008).

M a t e r i a l . Leaf impressions (Monte Tondo MSF1951, MSF1952, MSF1607).

***Populus* Linnaeus**
cf. *Populus* sp.

Pl. 10, Fig. 8

Triangular bract 3.5 to 7 mm long and 1.5 mm wide, attenuate apex and rounded base surface covered by spiny laciniate, up to 1 mm long. Bracts of this type have usually been assigned to a poplar (Heer 1856, Unger 1867) without any specific determination. Even the generic determination is uncertain.

M a t e r i a l . Bract impressions (Monte Tondo MSF1894; Tossignano MSF243).

Aceraceae Jussieu

***Acer* Linnaeus**
***Acer* cf. *integrilobum* Unger**

Pl. 10, Fig. 9–10

Incomplete leaf and fragments palmately 3-lobed, 24 to 67 mm long and 27 to 81 mm wide, medial and lateral lobes widely oblong to triangular, apices shortly attenuate, base cordate with petiole up to 12 mm long, margin entire, sinus acute, widely opened, venation basal actinodromous, primary veins strong, moderate, secondary veins thinner, alternate, looping, tertiary veins alternate to opposite percurrent, curved to sinuous, venation of the higher orders regular polygonal reticulate, areolation well developed, 3- to 4-sided.

Maple foliage characterized by such a trilobate form with almost entire lobes was revised by Walther (1972) who proposed a new concept for *A. integrilobum* and we adhere to his concept. The leaf figured on pl. 10, fig. 10 may also resemble *Trichosanthes* Linnaeus (Kvaček et al. 2008, pl. 9, fig. 13), however without cuticles the assignment is doubtful.

M a t e r i a l . Leaf impressions (Monte Tondo MSF1500, MSF1501, MSF1502, MSF1503, MSF1509).

***Acer* cf. *integerrimum* (Viviani) Massalongo**

Pl. 10, Fig. 13–14

Incomplete leaf and fragments palmately 5-lobed, 51 to 83 mm long and 51 to 98 mm wide, medial and lateral lobes oblong to triangular, apices shortly attenuate and blunt, base deeply cordate with petiole up to 17 mm long, margin entire, sinus rounded, widely opened, venation basal actinodromous, primary veins strong, moderate, secondary veins thinner, alternate, looping, tertiary veins alternate to opposite percurrent, curved to sinuous, venation of the higher orders regular polygonal reticulate, areolation well developed, 3- to 4-sided.

The presented pentalobate maple leaves with almost entire-margined lobes fit into the concept of *A. integerrimum*, as currently accepted (e.g., Bůžek 1971).

M a t e r i a l . Leaf impressions (Monte Tondo MSF1504, MSF1505, MSF1507).

***Acer* sp.**

Pl. 10, Fig. 11–12

Fruits samaroid, 26 and 23 mm long, 6 and 7 mm wide, nutlet at basal end, smaller, inflated, broadly oval, 2 and 3 mm in diameter, surface of nutlet poorly preserved, wing with a widely convex distal margin, proximal margin straight, apical margin rounded, 10 to 11 veins coalesced along proximal margin, wing veins diverging at angles of 20–30°, bifurcating 1 to 3 times.

Maple fruits are usually not assignable to associated foliage; therefore we do not attempt any specific determination in this respect.

M a t e r i a l . Fruits (Monte Tondo MSF1506; Tossignano MSF244).

Rutaceae Jussieu

***Chaneya* Wang et Manchester**
***Chaneya* cf. *membranosa* (Goeppert) Manchester et Zastawniak**

Pl. 11, Fig. 1

A rounded fruit with a pentamerous presistant corolla (only 4 preserved), 15 mm in diameter, free widely elliptical petals, apices obtuse, 5 primary longitudinal sub-parallel veins radiating from the petal base, straight, secondaries thinner, at acute angles, meeting with adjacent veins, looping at the margin, higher-order veins commonly forming polygonal areoles or loops at the margin.

The fruits have been described from the Neogene deposits of Europe under various genera, such as *Getonia* Roxburgh, *Porana* Burman, *Hydrangea* Linnaeus (for synonyms see Teodoridis and Kvaček 2005, Manchester and Zastawniak 2007).

M a t e r i a l . Fruit (Monte Tondo MSF1550).

Simaroubaceae de Candolle

Ailanthus Desfontaines
cf. *Ailanthus pythii* (Unger) Kovar-Eder et Kvaček

Pl. 11, Fig. 2–4

Incomplete leaflets and fragments subsessile to shortly petiolulate, asymmetric oblong to elliptic, 32 to 92 mm long and 19 to 32 mm wide, base cuneate, apex acuminate to acute, margin entire, venation brochiodromous, primary veins distinct, moderate, straight, secondary veins thinner, opposite to alternate, curved, numerous, at angles of 40–70°, tertiary veins alternate perpendicular, sinuous, venation of the higher orders regular polygonal reticulate, areolation well developed, 3- to 4-sided.

These shortly petiolulate slightly falcate to S-shaped leaflets with entire or undulate margins are most comparable with the type material from the middle Miocene site Parschlug (Kovar-Eder et al. 2004). However the assignment may not be without problems as the leaves are also similar to leaf morphotype of "*Sapindus*" *falcifolius* (A. Braun) A. Braun (see Kvaček et al. 2011).

Material. Leaflets (Monte Tondo MSF1510, MSF1511, MSF1512, MSF1513, MSF1514, MSF1515, MSF1516, MSF1517, MSF1518, MSF1519, MSF1520, MSF1521, MSF1522, MSF1523; Tossignano MSF11, MSF218).

Cornaceae Berchtold ex J. Presl

Nyssa Gronovius ex Linnaeus
Nyssa disseminata (Ludwig) Kirchheimer

Pl. 11, Fig. 6

Secondarily flattened endocarps, ovate to elliptic 18 and 19 mm long, 9 and 11 mm wide, apex acute to obtuse, base asymmetric rounded to cuneate, orbicular dehiscence valve at the apex, 3 mm in diameter, upper surface longitudinally ribbed, 8 and 9 in number.

Elliptic endocarps preserved as impressions are assignable to *Nyssa disseminata* (Ludwig) Kirchheimer because the length is less than 20 mm and there is a broad dehiscence valve covering the majority of the stone's width. This species is common in a few Pliocene sites in Italy (Martinetto 1995, Forno et al. 2015), but is here recorded for the first time in Miocene sediments.

Material. Endocarps (Monte Tondo MSF1830, MSF1831).

cf. *Nyssa* sp.

Pl. 11, Fig. 5, 7

Incomplete leaf widely elliptic to obovate, 33 to 92 mm long and 30 to 58 mm wide, apex not preserved, base probably broadly cuneate, margin entire, venation brochidodromous, midrib strong and straight, secondaries distinctly thinner, alternate, curved, looping, rarely forked, tertiary veins alternate to opposite percurrent, straight to sinuous, venation of the higher orders well developed, areolation 3- to 4-sided, veinlets lacking.

We treat several impressions of entire-margined leaves as part of the same plant that produced the endocarps described above, although definite evidence of generic affinity based on epidermal anatomy is not available.

Material. Foliage (Monte Tondo MSF1832, MSF1833, MSF1834, MSF1835, MSF1836).

Theaceae Mirbel
cf. *Theaceae* gen. et sp. indet.

Pl. 11, Fig. 8–9

Incomplete probably ovate leaf, up to 62 mm long and 44 mm wide, apex probably acute or shortly attenuate, base not preserved, margin simple serrate, teeth close, glandular, blunt, sinus angular, venation semicraspedodromous, primary veins distinct, moderate, secondary veins thinner, alternate, looping, at angles of 40–60°, tertiary veins alternate perpendicular, sinuous to curved, forked, venation of the higher orders regular polygonal reticulate, areolation well developed, 4-sided.

The leaf impression with glandular teeth shows features characteristic of several foliage types of the Theaceae (cf. Kvaček and Walther 1984a, b). Due to the lack of epidermal features this determination must remain only tentative.

Material. Leaf impression (Monte Tondo MSF1988).

Araliaceae Jussieu

Hedera Linnaeus
Hedera sp.

Pl. 11, Fig. 10–11

Leaf rhomboidal, 36 mm long and 22 mm wide, apex attenuate, base widely cuneate, margin entire, venation brochidodromous, midrib straight, secondaries alternate at angles of 10 to 30°, curved, looping, often forked, tertiary veins alternate to opposite percurrent, sinuous, venation of the higher orders poorly preserved.

The rhomboidal leaf with peculiar steep secondary venation is comparable with *Hedera multinervis* Kolakovski, recovered from the late Miocene deposits of Abkhazia and Greece (Kolakovski and Shakryl 1978, Kvaček et al. 2002, Velitzelos et al. 2014).

Material. Leaf impression (Monte Tondo MSF1618).

Familia incerta

Pungiphyllum Frankenhäuser et Wilde
Pungiphyllum cruciatum (A. Braun) Frankenhäuser et Wilde

Pl. 11, Fig. 12–13

Leaves (or ?leaflets) subsessile, lamina broadly oval, 45 to 57 mm long, 16 to 36 mm wide, base widely cuneate, apex broadly triangular, spiny, margin coarsely dentate, with a thick marginal sclerenchyma strand, teeth large, spiny, palmately disposed, 2 or 3 preserved per side, sinus rounded, venation craspedodromous, midrib strong, moderate, straight to curved, secondary veins alternate or subopposite at basal part, straight or slightly curved, at angles of 40–60°, tertiary

veins distinct, straight to sinuous, alternate, percurrent, often looping by the margin, venation of the higher orders regular polygonal reticulate, areolation distinct to moderately developed, 3- to 4-sided, veinlets dichotomous branching.

This fossil species characterised by widely, sharply dentate-lobed foliage, has often been encountered, always as an accessory element in various European Oligocene and Neogene floras (e.g., Kvaček and Walther 1981 as *"Quercus" cruciate*, Hably 1985, Kvaček et al. 2011). Its affinity has not yet been fully clarified.

M a t e r i a l . Foliage impressions (Monte Tondo MSF1904, MSF1905, MSF1906).

Phyllites Brongniart
Phyllites sp.

Pl. 12, Fig. 1

The illustrated entire-margined, strap-shaped foliage fragment slightly narrowing towards one end, 48 mm long and 5 to 10 mm wide, with a midrib and two rows of irregularly placed dots on either side near the margin (12 and 13 dots) can be best interpreted as a dicot leaf bearing trace fossils (bodies of fungal or animal origin), although the pattern also resembles fern sori.

M a t e r i a l . Foliage fragment (Monte Tondo MSF1849, MSF1850).

Carpolites Sternberg
Carpolites sp. 1

Pl. 12, Fig. 2–3

Disseminules, partly bi-spherical, 8 and 9 mm in diameter, radially striated, without details necessary for a clear determination. Sample MSF1543 may also represent a *Tetraclinis* cone.

M a t e r i a l . ?Fruits, seeds, cones (Monte Tondo MSF1537, MSF1543).

Carpolites sp. 2

Pl. 12, Fig. 4

A seed impression and its counter-impression widely obovate, 3 mm long and 2 mm wide, with an obovate embryo cavity, is similar to much larger seeds, which are produced by some Cucurbitaceae, e.g., *Trichosanthes* (Kirchheimer 1957, pl. 26, fig. 113a).

M a t e r i a l . Seed impressions (Monte Tondo MSF1539, MSF1540).

Carpolites sp. 3

Pl. 12, Fig. 5

The illustrated impression of a strongly flattened disseminule is ovoid in outline with a short terminal projection, 10 mm long and 6 mm wide, inside exhibiting two small symmetrically orientated traces, which may also represent an isolated *Pinus* seed.

M a t e r i a l . ? Seed impression (Tossignano MSF242).

Dicotylophyllum Saporta
Dicotylophyllum sp. 1

Pl. 12, Fig. 7–8

Leaves simple obovate, 16 to 35 mm long and 6 to 15 mm wide, apex obtuse and blunt or emarginate, base cuneate narrowed to thick petiole up to 2 mm long, margin entire, venation brochidodromous, midrib straight, secondaries, alternate at angles of 40–50°, straight, looping, tertiary veins alternate to opposite percurrent, sinuous, venation of the higher orders regular polygonal reticulate, areolation distinctly developed, 3- to 4-sided.

These spatulate leaves are of unknown affinity and were in older literature (e.g., Ettingshausen 1853, Heer 1859, Unger 1867) assigned to Sapotaceae. This sort of foliage requires epidermal studies.

M a t e r i a l . Leaf impressions (Monte Tondo MSF1590, MSF1591, MSF1592, MSF1593, MSF1594, MSF1595, MSF1596, MSF1597, MSF1598, MSF1599; Tossignano MSF313).

Dicotylophyllum sp. 2

Pl. 12, Fig. 10

Leaf lanceolate, 21 mm long and 7 mm wide, apex shortly attenuate, base cuneate, margin coarsely serrate in the upper part, teeth acute, sinuses angular, venation simply craspedodromous, midrib strong, straight, secondaries thinner, straight, steep, subopposite at angles of 20 to 30°, venation of the higher orders not preserved.

A slender lanceolate leaf impression, in its steep secondary venation resembling *Phyllites kvacekii* Bůžek (Bůžek 1971, pl. 43, figs 1–16) from the early Miocene deposits of the North Bohemian Basin.

M a t e r i a l . Leaf impression (Tossignano MSF620).

Dicotylophyllum sp. 3

Pl. 12, Fig. 11

Leaf obovate, 78 mm long, 37 mm wide, apex obtuse, base cuneate with fragmentary petiole 4 mm long, margin entire, venation brochidodromous, midrib strong, moderate, straight, secondary veins thinner, straight or curved, looping by margin, alternate, originating at angles of 30–50°, tertiary veins perpendicular, straight to sinuous, venation of the higher orders regular polygonal reticulate, areolation well developed, 4-sided, veinlets lacking.

The leaf impression is not identifiable without epidermal study, but we can not exclude its affinity to Lauraceae or Magnoliaceae.

M a t e r i a l . Leaf impression (Tossignano MSF279).

Dicotylophyllum sp. 4

Pl. 12, Fig. 12

Leaf small, rounded, 10 mm in diameter, apex emarginated, base widely cuneate with small petiole 1 mm long, margin entire, venation brochidodromous, midrib strong, moderate, curved, secondary veins thinner, curved,

looping by margin, alternate, basal pair opposite, at angles of 30° to 50°, tertiary veins perpendicular, straight to sinuous, venation of the higher orders poorly preserved.

The leaf may represent an aberrant specimen of *Smilax miohavanensis* Denk, D. Velitzelos, T. Güner et Ferrufino-Acosta (Denk et al. 2015) = *Mahonia* ? *aspera* (Unger) Kovar-Eder et Kvaček (Kovar-Eder et al. 2004) or a morphotaxon of Leguminosae gen et. sp. indet.

M a t e r i a l . Leaf impression (Monte Tondo MSF1600).

Dicotylophyllum sp. 5

Pl. 12, Fig. 13

Leaflet/leaf shortly petiolulate/petiolate, widely elliptic, 22 mm long and 18 mm wide, base widely cuneate, apex incomplete probably obtuse, margin crenualate, teeth close, blunt, sinus angular, venation semicraspedodromous, midrib strong, moderate, straight, secondary veins thinner, curved, looping by the margin, alternate, at angles of 40–60°, tertiary veins alternate to opposite percurrent, straight to sinuous, venation of the higher orders regular polygonal reticulate, areolation well developed, areoles 3- or 4-sided.

The rounded leaflet (? leaf) may resemble a detached *Rosa* leaflet.

M a t e r i a l . Foliage impression (Monte Tondo MSF1601, MSF1602).

Dicotylophyllum sp. 6

Pl. 12, Fig. 9

Leaf simple obovate, 28 mm long and 14 mm wide, apex incomplete probably obtuse, base cuneate, margin indistinctly coarsely dentate, teeth blunt, venation semicraspedodromous, midrib straight, secondaries, alternate at angles of 20–30°, straight, looping, tertiary veins alternate to opposite percurrent, sinuous, venation of the higher orders regular polygonal reticulate, areolation distinctly developed, 3- to 4-sided.

The leaf can be compared with foliage of some *Berberis*.

M a t e r i a l . Leaf impression (Monte Tondo MSF1589).

Dicotylophyllum sp. 7

Pl. 12, Fig. 15

Leaf ovate, 15 mm long and 8 mm wide, apex acute, base deeply cordate, margine entire, venation ?brochidodromous, midrib straight, secondaries opposite, curved probably looping, venation of the higher orders poorly preserved.

The leaf may also represent a small stipule.

M a t e r i a l . Leaf impression (Monte Tondo MSF1603).

Dicotylophyllum sp. 8

Pl. 12, Fig. 16

Leaf elliptical 24 mm long and 9 mm wide, apex blunt, base widely cuneate with complete petiole 6 mm long, margin entire, venation brochidodromous, primary vein distinct, moderate, secondary veins thinner, coarsely spaced, indistinct, subopposite to alternate, straight, looping close to the distinct intramarginal vein, venation of the higher orders poorly preserved.

The leaf resembles *Buxus* Linnaeus. However, the venation details such as intramarginal vein, less dense secondary veins contradict this determination.

M a t e r i a l . Leaf impressions (Monte Tondo MSF1531, MSF1604).

Plant incertae sedis

Pl. 12, Fig. 6

A spiral tendril 26 mm long and 2 mm wide of unknown affinity, may resemble the distal part of fern foliage.

M a t e r i a l . ? A spiral tendril (Monte Tondo MSF1541, MSF1542).

Compositions of the Tossignano and Monte Tondo plant assemblages

The leaf material of Tossignano collected by G. Scarabelli in the 19th century, is housed within the collections of the Museo "G. Scarabelli" di Imola. The original material and determinations by G. Scarabelli, i.e., *Bambusium sepultum* Massalongo, *Poacites laevis* Heer, *Chamaecyparites hardtii* Endlicher, *Araucarites sternbergii* Goeppert, *Sequoja langsdorfi* Heer, *Pinites goethanus* Unger, *Podocarpus eocenica* Unger, *Quercus* sp., *Ulmus plurinervia* Unger, *Laurus* sp., *Diospyros incerta* Massalongo and *Cassia tecomaefolia* Massalongo, had not been revised until the present day. The flora of Tossignano, preserved as leaf and carpological material, so far includes 41 vascular plant taxa – 8 conifers, 33 angiosperms (30 dicots and 3 monocots). The plant material of Monte Tondo yielded 74 vascular plant taxa – 11 conifers, 63 angiosperms (59 dicots, 3 monocots, 1 plant incertae sedis) – see Table 1. The carpological record is very scanty, being limited to *Tetraclinis*, *Taxodium* and *Pinus* cones, as well as seeds of *Pinus* sp. div. and fruits of *Acer*, cf. *Liquidambar* and *Ulmus*. This material has been recently revised and its morphological aspect specified. Focusing on a floristic comparison of the Tossignano and Monte Tondo palaeofloras, the majority of taxa are shared, i.e., *Pinus* spp., *Sequoia*, *Taiwania*, *Tetraclinis*, *Cupressus*, cf. *Magnolia*, *Laurophyllum* spp., *Daphnogene*, *Potamogeton*, *Bambusa*, Poaceae vel Cyperaceae, *Platanus*, *Liquidambar*, *Engelhardia*, Leguminosae spp., *Ulmus*, *Quercus* spp., *Trigonobalanopsis*, *Fagus*, *Pterocarya*, *Carpinus*, cf. *Populus*, *Acer*, cf. *Ailanthus* and *Dicotylophyllum* spp. Several taxa occur only at Monte Tondo, i.e., *Cupressoconus*, *Chamaecyparis*, *Ocotea*, *Berberis, Rosa*, cf. *Pyracantha,* cf. *Photinia*, Rosaceae, cf. *Berchemia*, *Zelkova*, *Myrica*, cf. *Betula*, *Carya*, *Salix*, *Chaneya*, *Nyssa*, *Hedera*, cf. Theaceae, *Pungiphyllum* and *Phyllites*, while cf. *Glyptostrobus*, *Carpinus* cf. *betulus* and *Alnus cecropiifolia* are exclusively recorded at Tossignano (see detail in Table 1). Both palaefloras treated here are floristically very similar to other known Messinian plant assemblages e.g., from northern-central Italy (Kovar-Eder et al. 2006, Bertini and Martinetto 2008, 2011), France (Roiron 1991) and Greece (Kvaček et al. 2002, Velitzelos et al. 2014).

Table 1. Summary of the floristic composition of the studied plant assemblages of Tossignano and Monte Tondo.

Taxon	Studied sites		Nearest Living Relatives (NLR)
	Tossignano	Monte Tondo	
Acer cf. *integerrimum* (VIVIANI) MASSALONGO		*	*Acer* sect. *Acer* LINNAEUS
Acer cf. *integrilobum* UNGER		*	*Acer* sect. *Palmata* PAX (*A. palmatum* THUNBERG, *A. japonicum* THUNBERG, *A. sieboldianum* MIQUEL, *A. circinatum* PURSH)
Acer sp.	*	*	*Acer* sp.
cf. *Ailanthus pythii* (UNGER) KOVAR-EDER et KVAČEK	*	*	unknown
Alnus cecropiifolia (ETTINGSHAUSEN) BERGER	*		*Alnus hirsuta* TURCZANINOW ex RUPRECHT, *A. oblongifolia* TORREY
Alnus cf. *menzelii* RANIECKA-BOBROWSA		*	*Alnus serrulata* (AITON) WILLDNOW, *A. subcordata* C.A. MEYER
Bambusa sp.	*	*	*Bambusa* sp.
Berberis cf. *teutonica* (UNGER) KOVAR-EDER et KVAČEK		*	*Berberis* sp.
cf. *Berchemia* sp.		*	unknown
cf. *Betula* sp.		*	Betulaceae
Carpinus cf. *betulus* LINNAEUS	*		*Carpinus betulus* LINNAEUS
Carpinus cf. *orientalis* MILLER		*	*Carpinus orientalis* MILLER
Carpolites sp. 1		*	unknown
Carpolites sp. 2		*	unknown
Carpolites sp. 3	*		unknown
Carya sp.		*	*Carya* sp.
Chamaecyparis sp.		*	*Chamaecyparis* sp.
Chaneya cf. *membranosa* (GOEPPERT) MANCHESTER et ZASTAWNIAK		*	Rutaceae
Cupressoconus sp.		*	unknown
Cupressus rhenana (KILPPER) MAI et VELITZELOS	*	*	*Cupressus* sp.
Daphnogene polymorpha (A. BRAUN) ETTINGSHAUSEN	*	*	*Cinnamonum* sp.
Dicotylophyllum sp. 1	*	*	unknown
Dicotylophyllum sp. 2	*		unknown
Dicotylophyllum sp. 3	*		unknown
Dicotylophyllum sp. 4		*	unknown
Dicotylophyllum sp. 5		*	unknown
Dicotylophyllum sp. 6		*	unknown
Dicotylophyllum sp. 7		*	unknown
Dicotylophyllum sp. 8		*	unknown
Engelhardia (sect. *Palaeocarya*) *macroptera* (BRONGNIART) UNGER	*	*	*Engelhardia* vel *Oreomunnea* OERSTED
Fagus gussonii MASSALONGO emend. KNOBLOCH et VELITZELOS	*	*	*Fagus* sp. (Europe)
cf. *Glyptostrobus* sp.	*		Cupressaceae
Hedera sp.		*	*Hedera* sp.
cf. *Laurophyllum pseudoprinceps* WEYLAND et KILPPER	*	*	Lauraceae vel Magnoliaceae
Laurophyllum sp. 1	*	*	Lauraceae
Laurophyllum sp. 2	*	*	Lauraceae
Leguminosae gen. et sp. indet. 1	*	*	Leguminosae
Leguminosae gen. et sp. indet. 2	*	*	Leguminosae
Leguminosae gen. et sp. indet. 3		*	Leguminosae
Leguminosae gen. et sp. indet. 4	*	*	Leguminosae
Liquidambar europaea A. BRAUN / cf. *L. magniloculata* CZECZOTT et SKIRGIEŁŁO	*	*	*Liquidambar styraciflua* LINNAEUS, *L. orientalis* LINNAEUS
cf. *Liquidambar* sp.		*	unknown
cf. *Magnolia liblarensis* (KRÄUSEL et WEYLAND) KVAČEK	*	*	Magnoliaceae vel Lauraceae
Myrica lignitum (UNGER) SAPORTA		*	*Myrica* sp.
Nyssa disseminata (LUDWIG) KIRCHHEIMER		*	*Nyssa sylvatica* MARSHALL
cf. *Nyssa* sp.		*	unknown
Ocotea heerii (GAUDIN) TAKHTAJAN		*	*Ocotea* sp.
cf. *Photinia* sp.		*	Rosaceae
Phyllites sp.		*	unknown
Pinaceae gen. indet.	*		Pinaceae
Pinus cf. *rigios* (UNGER) ETTINGSHAUSEN	*	*	*Pinus* sp.
Pinus paleostrobus ETTINGSHAUSEN	*	*	*Pinus* sect. *Strobus* SPACH
Pinus sp. (cone)	*	*	*Pinus* sp.
Pinus sp. div. (seed)		*	*Pinus* sp.
Platanus leucophylla (UNGER) KNOBLOCH	*	*	*Platanus occidentalis* LINNAEUS
Plant incertae sedis		*	unknown
Poaceae vel Cyperaceae gen. et sp. indet.	*	*	Poaceae
cf. *Populus* sp.	*	*	unknown
Potamogeton sp.	*	*	*Potamogeton* sp.

Add. Table 1.

Taxon	Studied sites		Nearest Living Relatives (NLR)
	Tossignano	Monte Tondo	
Pterocarya paradisiaca (UNGER) ILJINSKAYA	*	*	*Pterocarya fraxinifolia* SPACH
Pungiphyllum cruciatum (A. BRAUN) FRANKENHÄUSER et WILDE		*	unknown
cf. *Pyracantha* sp.		*	Rosaceae
Quercus kubinyii (KOVATS ex ETTINGSHAUSEN) CZECZOTT vel *Q. drymeja* UNGER	*	*	*Quercus* sect. *Cerris* LOUDON
Quercus mediterranea UNGER	*	*	*Quercus* sect. *Cerris* LOUDON
Quercus pseudocastanea GOEPPERT		*	*Quercus* sect. *Cerris* LOUDON
Quercus roburoides GAUDIN	*	*	*Quercus petraea* LIEBL
Quercus sp. (fruit)		*	*Quercus* sp.
cf. *Quercus* sp. div.	*	*	unknown
Rosa sp.		*	*Rosa* sp.
Rosaceae gen. et sp. indet. 1		*	unknown
Rosaceae gen. et sp. indet. 2		*	unknown
Salix sp.		*	*Salix* sp.
Sequoia sp.	*	*	*Sequoia sempervirens* (D. DON) ENDLICHER
Taiwania sp.	*	*	*Taiwania cryptomerioides* HAYATA
Taxodium dubium (STERNBERG) HEER	*	*	*Taxodium* sp.
Tetraclinis salicornioides (UNGER) KVAČEK	*	*	*Tetraclinis articulata* (VAHL) MASTERS
cf. Theaceae gen. et sp. indet.		*	Theaceae
Trigonobalanopsis rhamnoides (ROSSMÄSSLER) KVAČEK et WALTHER	*	*	*Trigonobalanus* sp., *Castanopsis* sp.
Ulmus plurinervia UNGER	*	*	*Ulmus parvifolia* JACQUIN
Ulmus sp. (fruit)		*	*Ulmus* sp.
Zelkova zelkovifolia (UNGER) BŮŽEK et KOTLABA		*	*Zelkova* sp.

Palaeoenvironmental analysis

Generally, the vegetation of Monte Tondo and Tossignano can be characterized by a relatively high frequency of zonal elements and conifers. Three specific vegetation assemblages can be distinguished based on the phytosociological approach. The vegetation assemblages differ in their plant compositions (depending on specific ecological conditions of the biotopes) and mutually integrate on their ecotons. The first vegetation assemblage is mixed-swamp forest, which is typical of plant elements preferring an environments with relatively low dynamics (stagnant water table or periodical, relatively long-lasting floods). This vegetation type is typical of the marginal zone of basins or oxbow lakes in a fluvial system and includes characteristic plant elements which do not occur frequently in the studied sites: cf. *Glyptostrobus* (E3), *Taxodium dubium* (E4), *Myrica lignitum* (E2), *Sequoia* (E3) and Poaceae vel Cyperaceae (E1), *Potamogeton* (E1). The next vegetation assemblage is characterised by plants, which permanently occupy a waterlogged (wet soil) substrate. It is a riparian assemblage containing *Sequoia* (E3), cf. *Berchemia* (E2), *Nyssa* (E2–3), *Liquidambar* (E2–E3), *Ulmus plurinervia* (E2–3), *Salix* (E2), cf. *Magnolia* (E2–3), *Populus* (E2–3), *Platanus leucophylla* (E3–4), *Bambusa* (E1–2), and Poaceae vel Cyperaceae (E1). The most diverse vegetation assemblage, limited to well-drained habitats, is a zonal mesophytic (mesic) assemblage characterized by the associated occurrence of the following angiosperms: *Daphnogene polymorpha* (E3), *Ocotea heeri* (E3), *Laurophyllum* spp. (E2–3), cf. Theaceae gen. et sp. indet. (E2–3), *Berberis teutonica* (E2), *Fagus gussonii* (E3), *Quercus* spp. (E3), *Trigonobalanopsis rhamnoides* (E4), *Alnus* spp. (E2–3), cf. *Betula* (E2–3), *Carpinus* (E2), *Pterocarya paradisiaca* (E3–4), *Carya* (E3–4), *Engelhardia* (E3), *Zelkova zelkovifolia* (E4), Leguminosae spp. (E2–E3), *Pungiphyllum cruciatum* (E2–3), cf. *Pyracantha* (E1–2), *Rosa* (E2), cf. *Photinia* (E2–3), Rosaceae (E2–3), *Hedera* (E1–2), *Acer* spp. (E2–3), cf. *Ailanthus pythii* (E3–4), *Chaneya* (E2), *Dicotylophyllum* spp. (E2–4), *Bambusa* (E1–2), and conifers *Pinus* spp. (E3), *Tetraclinis salicornioides* (E2), *Chamecyparis* (E3), *Taiwania* (E3), *Cupressus rhenana* (E3) and *Cupressoconus* (E3). The aforementioned general vegetation structure of the Monte Tondo and Tossignano plant assemblages corresponds to the vegetation transect of the Evaporitic Messinian (Scaparoni) type published by Bertini and Martinetto (2011, Fig. 2A). The authors distinguished swamp, riparian vegetation, zonal "subtropical humid forest" sensu Bertini and Martinetto (2008) and upland vegetation defined on the basis of the studied pollen records.

The plant assemblages of Monte Tondo and Tossignano were also evaluated using the IPR-vegetation analysis (Kovar-Eder et al. 2008, Teodoridis et al. 2011). We added the pollen record already known from Tossigniano locality (Bertini 1994, 2006) and summarized in Bertini and Martinetto (2011). Their results of the IPR vegetation analysis for the Monte Tondo plant assemblage, based on the macro-records, shows the following ratio of key components, i.e., broad-leaved deciduous (BLD) – 56 %, broad-leaved evergreen (BLE) – 29 %, sclerophyllous + legume-like (SCL + LEG) – 15 % and dry herbaceous + mesophytic herbaceous /zonal herbaceous/ (D-HERB + M-HERB /ZONAL HERB/) – 1 %. Similar results were obtained from evaluation of all available (macro + pollen) records from Tossignano, the

Table 2. Results of the IPR vegetation analysis derived from the plant assemblages of Tossignano and Monte Tondo and other selected Messinian sites from Europe. Symbols: L (leaf flora), F (fruit and seed flora), P (pollen flora), ShSF (Subhumid Sclerophyllous Forest), MMF (Mixed Mesophytic Forest), BLEF (Broad-leaved Evergreen Forest), BLEF/MMF (transition vegetation between Broad-leaved Evergreen Forest and Mixed Mesophytic Forest), BLDF/MMF (transition vegetation between Broad-leaved Deciduous Forest and Mixed Mesophytic Forest) and OW (Open woodland).

Localities	Organs	% of BLD component	% of BLE component	% of SCL + LEG component	% DRY herb component	% MESO herb component	% of zonal herbaceous component	Number of zonal taxa	Number of zonal woody angiosperms	Total number of taxa	Classification sensu Kovar-Eder et al. (2008)	Classification sensu Teodoridis et al. (2011)
Monte Tondo	F + L	56.4	29.0	14.6	0	1.0	1.0	56	46	68	-	BLEF/MMF
Tossignano	F+L+P	54.4	25.1	19.6	12.0	6.8	18.9	77	55	100	-	BLEF/MMF
	F+L	58.1	32.3	9.6	0	1.6	1.6	32	24	41	-	BLEF
	P	51.5	19.4	27.5	20.8	10.6	31.4	45	31	59	-	OW
Gabbro near Livorno*	L	48	21	31	0	0	0	58	30	68	ShSF	? ShSF
Vegora	L	56	15	26	0	0	0	34	27	46	ShSF	? ShSF
Murat	L	75	13	12	0	0	0	34	30	43	MMF	MMF, BLDF/MMF
Cheylade	L	75	13	13	0	0	0	17	16	29	MMF	MMF, BLDF/MMF
Realmonte salt mine	P	47	21	28	17	16	33	28	44	57	OW	OW
Racalmuto salt mine	P	46	22	30	15	20	35	30	67	103	OW	OW
	P	49	21	25	14	16	30	25	41	58	OW	OW

*composite flora from two quite different stratigraphic intervals

values of BLD, BLE, SCL + LEG and ZONAL HERB are 54%, 25%, 20% and 19%. The last key component – ZONAL HERB, shows a significant difference exceeding 17 % which is caused by evaluation of the pollen record in Tossignano (see Table 2). According to the thresholds for the key components (sensu Teodoridis et al. 2011), the results of IPR vegetation analysis predict a transition (ecotone) vegetation type between "Broad-leaved Evergreen Forest" and "Mixed Mesophytic Forest (BLEF/MMF)" for the Monte Tondo and Tossignano plant assemblages. The partial IPR vegetation results for Tossignano (i.e., evaluation of the macro and pollen records separately) estimate zonal vegetation types of "Broad-leaved Evergreen Forest (BLEF)" for the macro plant record and "Zonal xeric open woodlands (OW)" for the studied pollen record.

While the lack of a dry herbaceous component (caused by absence of the pollen record) may allow interpretation of the zonal vegetation type of Monte Tondo in the upland area as closed canopy MMF/BLEF forest, the plant assemblage of Tossignano, due to its high abundance of DRY HERB component (up to 20 %), may be interpreted as a more open forest environment (Table 2). At first sight, this fact does not correspond with the opinion of Bertini and Martinetto (2011, p. 242), who noted the poor representation of non-aquatic herbs in northern Italian pollen records (including Tossignano) in strong contrast with the high pollen percentage in southern Italian records where xeric conditions occurred before, during, and after the evaporitic phases (e.g., Suc and Bessais 1990, Suc et al. 1995 a, b, Bertini et al. 1998). Kovar-Eder et al. (2008) published IPR-vegetation results based on the pollen spectrum of the Messinian Realmonte salt mine (Sicily), where the values of DRY HERB component are lower than those of Tossignano (see Table 2). Focusing on the IPR results of the pollen records, a only *Artemisia* LINNAEUS and *Lygeum* LOEFLING ex LINNAEUS, may be interpreted as "true" dry herb component, the rest of the dry herb elements of Tossignano representing equivocal taxa assigned mostly at the family level only (e.g., Apiaceae, Cichorioideae, Asteroideae, Cannabaceae, Poaceae, Saxifragaceae) and thus their IPR scores are always included within MESO herb and Azonal non-woody components. This fact may influence the reliability of the vegetation cover interpretation based on the IPR vegetation analysis, but does not affect the comparison of those IPR results derived from the same scoring methodology (see above).

Kovar-Eder et al. (2008) presented further results derived from other European Messinian localities, i.e., Vegora (Greece, Kvaček et al. 2002), Murat (France, Roiron 1991), Cheylade (France, Gilbert et al. 1977) and Gabbro (Italy, Berger 1957) – see Table 2. Comparing those with the vegetation assemblages of Monte Tondo and Tossignano (with the exception of the pollen record) the under-representation of the SCL + LEG components is obvious with a very close affinity to both the French sites. However, the suggested assignment of Vegora and Gabbro to vegetation assemblages of the Subhumid Sclerophyllous Forest (ShSF sensu Kovar-Eder et al. 2008) must be very tentative due to the lack of herbaceous elements in general which are very frequent in modern Mediterranean floras and their physiognomical equivalents in China and California (Ou et al. 2006, Tang 2006, Teodoridis et al. 2011). On the other hand, it may also be simply explained by the absence of a pollen record at these localities.

Palaeoclimatic results derived from the CLAMP technique (using the 144 site calibration dataset) estimate the balanced climatic character for Monte Tondo and Tossignano as follows: MAT (12.0 °C and 13.2 °C), WMMT (21.9 °C and 24.1 °C), CMMT (4 °C and 4.3 °C), 3-WET (1309 mm and 1277 mm) and 3-DRY (142 mm and 217 mm). The MAT proxies derived from the LMA for Monte Tondo and Tossignano (sensu Su et al. 2010) show comparable results for both studied sites, i.e., 14.3 °C and 13.8 °C (sampling error is 2.5 °C and 3.1 °C), which are both higher than the CLAMP estimates. This is probably due to a taphonomic factor expressed here by a minority of non-entire margined (mostly riparian) leaf elements.

The Coexistence Approach is applied using climatic requirements of modern plant taxa as cited in the Palaeoflora Database (Utescher and Mosbrugger in "The Palaeoflora Database", www.palaeoflora.de). In the CA analysis, 39 extant reference taxa of the Monte Tondo palaeoflora are combined with climate data, while for Tossignano the results are based on a total of 24 taxa. Climate data for *Tetraclinis* were not included in the analysis, due to the outlier status of the taxon (Utescher et al. 2014). As regards *Sequoia* we use climatic requirements of the Taxodioideae subfamily. Moreover, taxa with uncertain taxonomic status (cf. identifications) are excluded from CA climate calculations. Climate data for a total of 7 variables obtained for both sites are presented in Table 3, and additionally for MAT, MAP and MPwarm as climatic range charts in Text-fig. 3–5. The Nearest Living Relatives used in the reconstruction are provided in Table 1 next to the fossil taxa. For all of the climate variables calculated, climatic ranges of the modern taxa used in the present NLR concept show a high degree of overlapping. The CA results indicate that both floras existed under comparable climatic conditions, which is in line with the relatively similar floral composition of the sites (see above). Compared to the temperature reconstruction using CLAMP, CA data are at the higher limit of the CLAMP confidence intervals as regards CMMT and WMMT values of both floras and MAT calculated for Tossignano (CLAMP: 13.2 °C; CA: 13.8–16.2 °C). For the Monte Tondo flora, CA results clearly point to a significantly higher MAT compared to CLAMP (12 °C / 16–16.5 °C) and hence to warmer conditions than at present (present-day MAT of the study area at sea-level: around 13.5 °C). This partial offset between CA and CLAMP when reconstructing palaeotemperature mainly concerns MAT and is already known from previous applications of both techniques on leaf floras from the European Neogene (Uhl et al. 2007). Possibly, this minor inconsistence can be related to insufficient representativeness of the CLAMP calibration dataset with regard to the European flora. However, both methods accordingly point to warm temperate conditions with mild winters and moderately warm summers. As regards precipitation both CLAMP and CA reconstruct a distinct seasonality of rainfall (3-wet near 1,300 mm; 3-dry 142 and 217 mm; MPwet 160–170 mm; MPdry 35–52 mm), but the rates reconstructed by CA are considerably lower in general (MAP in the order of 900–1,400 mm). With MPwarm being at 89–195 mm there is evidence from CA that the dry season was not during the summer in the study area, unlike in the present-day climate on the Adriatic coast.

Table 3. Climate data for the Monte Tondo and Tossignano floras as calculated by the CA. Symbols: MAT (Mean Annual Temperature), WMMT (Warmest Month Mean Temperature), CMMT (Coldest Month Mean Temperature), MAP (Mean Annual Precipitation), MPwet (Mean Precipitation in the Wettest Month), MPdry (Mean Precipitation in the Driest Month) and MPwarm (Mean Precipitation in the Warmest Month).

	Monte Tondo	Tossignano
number of taxa contributing with data	39	34
MAT [°C]	16–16.5	13.8–16.5
CMMT [°C]	3.1–5.8	3.1–5.8
WMMT [°C]	22.3–24.9	22.3–24.9
MAP [mm]	979–1356	979–1356
MPwet [mm]	160–170	160–170
MPdry [mm]	35–52 (2 intervals)	35–38
MPwarm [mm]	89–122	89–195
excluded taxa	*Tetraclinis*	*Tetraclinis*

All our climate data point to the existence of a warm temperate, primarily humid climate during the deposition of the leaf-bearing strata. This is in line with the mesic character of the zonal assemblages recovered from the sites (see above), and coincides with pollen-based vegetation reconstructions carried out for the same strata (subtropical humid forest; Bertini 2006; Bertini and Martinetto 2008). Moreover, climate data estimated from pollen records if using the Climate Amplitude Method (Adriatic pollen records for Borgo Tossignano, Monticino, Maccarone) provide climatic means for the Messinian that largely agree with our CA-based megafloral estimates (Fauquette et al. 2006). The high diversity and good taxonomic control in both megafloras presently analysed provide a better climatic resolution compared to previous results based only on pollen data. However, the inferred climatic conditions do not support the existence of xeric open woodlands as indicated by the IPR vegetation analysis of the pollen flora of Tossignano (see above).

On the other hand, it can be assumed that the Messinian rainfall patterns had large regional differences in the Mediterranean as suggested by the large mammal record (Eronen et al. 2011). Moreover, temperature and humidity were varying in time, depending on the precession/obliquity interference patterns in insolation causing the cyclic sedimentary facies changes (e.g., Roveri et al. 2014). It can be assumed that the organic-rich, laminated shales were deposited under warmer and more humid conditions compared to the selenite beds (cf. Krijgsman et al. 2001). As the leaf materials of both studied floras originate from the shale layers (see above), our climate data most likely represent the climate conditions during the warm and wet phases of the climate cycles expressed in the sedimentary successions. If assuming an age range of ca. 5.6–5.7 Ma for the leaf-bearing upper cycles of the Vena del Gesso Fm. our record corresponds with a distinct sea-level rise and global warming event including isotope stages TG17 through TG15 and culminating at 5.7 Ma (Roveri et al. 2014). Thus, the macrofloral record represents a globally warm climate phase within the Messinian being in line with the comparatively high temperature estimates obtained by the CA, and the thermophilous character of the vegetation.

Kvaček et al. (2002) characterized floristically, climatically and stratigraphically the comparable fossil flora of Vegora using the Coexistence Approach, it produced very similar estimates to those derived from the LMA and CLAMP techniques, i.e., MAT 13.3–14.6 °C, CMMT 0.4–4.5 °C, WMMT 23.8–24.6 °C, and MAP 897–1018 mm.

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Explanations to the plates

PLATE 1

Pinus sp.

1. Seed cone, Tossignano MSF55, scale bar 10 mm.

Pinus cf. *rigios* (Unger) Ettingshausen

2. Pine needle fascicle with two needles, Monte Tondo MSF1855, scale bar 10 mm.
3. Pine needle fascicle with three needles, Monte Tondo MSF1852, scale bar 10 mm.

Pinus paleostrobus Ettingshausen

4. Pine needle fascicle with five needles, Tossignano MSF36, scale bar 10 mm.

Pinus sp. div.

5. Pine seed, Monte Tondo MSF1869, scale bar 5 mm.

Pinaceae gen. indet.

6. Isolated needle, Tossignano MSF64, scale bar 5 mm.

Taiwania sp.

7. Foliage shoot, Monte Tondo MSF1957, scale bar 10 mm.
8. Foliage shoot, Monte Tondo MSF1954, scale bar 5 mm.

Sequoia sp.

9. Foliage shoot, Tossignano MSF232, scale bar 10 mm.

cf. *Glyptostrobus* sp.

10. Foliage shoot, Tossignano MSF235, scale bar 10 mm.
11. Branched twig, Tossignano MSF236, scale bar 10 mm.

Sequoia sp.

12. Seed, Monte Tondo MSF1953, scale bar 3 mm.

Taxodium dubium (Sternberg) Heer

13. Foliage shoot, Tossignano MSF37, scale bar 10 mm.

Chamaecyparis sp.

14. Foliage fragment, Monte Tondo MSF1546, scale bar 3 mm.
15. Foliage fragment, Monte Tondo MSF1547, scale bar 3 mm.

Cupressoconus sp.

16. Seed cone in cross section, Monte Tondo MSF1536, scale bar 3 mm.

Cupressus rhenana (Kilpper) Mai et Velitzelos

17. Seed cone in cross section, Tossignano MSF1555, scale bar 5 mm.

PLATE 2

Cupressus rhenana (Kilpper) Mai et Velitzelos

1. Foliage branches, Monte Tondo MSF1556, scale bar 5 mm.

Tetraclinis salicornioides (Unger) Kvaček

2. Fragmentary twig, Monte Tondo MSF1983, scale bar 5 mm.
3. Seed cone, Monte Tondo MSF1987, scale bar 5 mm.

cf. *Magnolia liblarensis* (Kräusel et Weyland) Kvaček

4. Leaf impression, Monte Tondo MSF1766, scale bar 10 mm.
5. Leaf compression, Tossignano M.D. 4660, scale bar 10 mm.
6. Fragmentary leaf impression, Monte Tondo MSF1765, scale bar 10 mm.
7. Detail of the previous Fig. 6, scale bar 5 mm.

Ocotea heeri (Gaudin) Takhtajan

8. Leaf impression, Monte Tondo MSF1838, scale bar 10 mm.
9. Leaf fragment showing venation, Monte Tondo MSF1837, scale bar 10 mm.
10. Leaf fragment showing venation, arrow indicate glands between midrib and basal secondary veins, Monte Tondo MSF1839, scale bar 10 mm.
11. Leaf impression, Monte Tondo MSF1563, scale bar 5 mm.
12. Elongate leaf impression, Monte Tondo MSF1561, scale bar 10 mm.

Daphnogene polymorpha (A. Braun) Ettingshausen

13. Broader leaf impression, Monte Tondo MSF1560, scale bar 10 mm.
14. Leaf compression, Tossignano MSF43, scale bar 10 mm.

Laurophyllum cf. *pseudoprinceps* Weyland et Kilpper

15. Fragmentary leaf base, Monte Tondo MSF1698, scale bar 10 mm.
16. Detail of the previous figure 15, scale bar 5 mm.

PLATE 3

Laurophyllum cf. *pseudoprinceps* Weyland et Kilpper

1. Leaf impression, Monte Tondo MSF1696, scale bar 10 mm.
2. Leaf compression, Tossignano MSF51, scale bar 10 mm.

Laurophyllum sp. 1

3. Narrow leaf impression, Tossignano MSF271, scale bar 10 mm.
4. Broad leaf impression, Monte Tondo MSF1622, scale bar 10 mm.
5. Leaf compression with venation details, Tossignano MSF14, scale bar 10 mm.
6. Leaf base, Tossignano MSF1637, scale bar 10 mm.

Laurophyllum sp. 2

7. Leaf impression, Monte Tondo MSF1664, scale bar 10 mm.
8. Petiolate leaf impression, Monte Tondo MSF1657, scale bar 10 mm.

PLATE 4

Laurophyllum sp. 2

1. Abnormal leaf impression with rounded apex, Tossignano MSF70, scale bar 10 mm.

Potamogeton sp.

2. Incomplete leaf impression showing venation details, Tossignano MSF40, scale bar 10 mm.
3. Complete leaf, Tossignano MSF41, scale bar 10 mm.

Bambusa sp.

4. Elongate leaf, Tossignano MSF337, scale bar 10 mm.
5. Leaf compression, Monte Tondo MSF1526, scale bar 10 mm.

Berberis cf. *teutonica* (Unger) Kovar-Eder et Kvaček
6. Leaf impression, Monte Tondo MSF1528, scale bar 5 mm.
7. Leaf impression, Monte Tondo MSF1527, scale bar 5 mm.

cf. *Liquidambar magniloculata* Czeczott et Skirgiełło
8. Globular infructescence, Monte Tondo MSF1757, scale bar 5 mm.
9. Globular infructescence, Monte Tondo MSF1758, scale bar 5 mm.

Platanus leucophylla (Unger) Knobloch
10. Impression of lobed leaf, Tossignano MSF31, scale bar 10 mm.
11. Impression of simple leaf, Monte Tondo MSF1874, scale bar 10 mm.
12. Detail of Fig. 11, scale bar 5 mm.

cf. *Liquidambar magniloculata* Czeczott et Skirgiełło
13. Globular infructescence, Tossignano MSF611, scale bar 5 mm.

cf. *Liquidambar* sp.
14. Detail of leaf fragment, Monte Tondo MSF1756, scale bar 10 mm.

PLATE 5

Liquidambar europaea A. Braun
1. Leaf impression, Monte Tondo MSF1754, scale bar 10 mm.

Leguminosae gen. et sp. indet. 1
2. Narrow leaflet, Tossignano MSF74, scale bar 10 mm.
3. Broader leaflet, Tossignano MSF334, scale bar 10 mm.
4. Larger leaflet, Tossignano MSF320, scale bar 10 mm.
5. Detail of the previous Fig. 4, scale bar 10 mm.

Leguminosae gen. et sp. indet. 2, scale bar 10 mm.
6. Apiculate leaflet, Monte Tondo MSF1734, scale bar 5 mm.
7. Detail of the previous Fig. 6, scale bar 2.5 mm.
8. Narrow leaflet, Tossignano MSF621, scale bar 5 mm.
9. Broader leaflet, Tossignano MSF621, scale bar 5 mm.

Leguminosae gen. et sp. indet. 3
10. Broad elliptical leaflet, Monte Tondo MSF1747, scale bar 10 mm.
11. Detail of the previous Fig. 10, scale bar 5 mm.
12. Incomplete leaflet base, Monte Tondo MSF1744, scale bar 10 mm.

PLATE 6

Leguminosae gen. et sp. indet. 4
1. Elongate leaflet, Monte Tondo MSF1751, scale bar 5 mm.
2. Rounded leaflet, Tossignano MSF1752, scale bar 5 mm.

Rosa sp.
3. Fragmentary leaflet, Monte Tondo MSF1947, scale bar 5 mm.
4. Leaflet, Monte Tondo MSF1948, scale bar 5 mm.

Rosaceae gen. et sp. indet. 1
5. Leaflet, Monte Tondo MSF1950, scale bar 10 mm.

Rosaceae gen. et sp. indet. 2
6. Incomplete serrate leaf, Monte Tondo MSF1907, scale bar 5 mm.

cf. *Pyracantha* sp.
7. Petiolate leaf, Monte Tondo MSF1915, scale bar 5 mm.
8. Long petiolate leaf, Monte Tondo MSF1909, scale bar 5 mm.

cf. *Berchemia* sp.
9. Long petiolate leaf, Monte Tondo MSF1529, scale bar 10 mm.

Ulmus plurinervia Unger
10. Leaf impression with venation, Monte Tondo MSF2003, scale bar 5 mm.

Ulmus sp.
11. Fruit, Monte Tondo MSF710, scale bar 5 mm.

Ulmus plurinervia Unger
12. Incomplete leaf impression, Monte Tondo MSF2001, scale bar 5 mm.

PLATE 7

Zelkova zelkovifolia (Unger) Bůžek et Kotlaba
1. Leaf impression, Monte Tondo MSF2008, scale bar 5 mm.
2. Leaf impression, Monte Tondo MSF2007, scale bar 5 mm.

Quercus sp.
3. Acorn impression, Monte Tondo MSF1920, scale bar 5 mm.

Quercus kubinyii (Kovats ex Ettingshausen) Czeczott vel. *Q. drymeja* Unger
4. Fragmentary leaf impression, Monte Tondo MSF1923, scale bar 10 mm.
5. Leaf compression, Tossignano MSF255, scale bar 5 mm.

cf. *Quercus* sp. div.
6. Short leaf impression, Monte Tondo MSF1921, scale bar 5 mm.

Quercus mediterranea Unger
7. Broad leaf impression, Monte Tondo MSF1926, scale bar 5 mm.
8. Narrow petiolate leaf, Monte Tondo MSF1927, scale bar 5 mm.
9. Narrow petiolate leaf, Monte Tondo MSF1925, scale bar 5 mm.

Quercus pseudocastanea Goeppert
10. Aberrantly short leaf, Monte Tondo MSF1938, scale bar 10 mm.
11. Leaf apex, Monte Tondo MSF1933, scale bar 10 mm.
12. Complete elongate leaf, Monte Tondo MSF1937, scale bar 10 mm.

cf. *Quercus* sp. div.
13. Leaf impression, Tossignano MSF257, scale bar 10 mm.

PLATE 8

Quercus roburoides Gaudin
1. Leaf impression, Tossignano MSF53, scale bar 10 mm.
2. Leaf impression, Tossignano MSF35, scale bar 10 mm.

Trigonobalanopsis rhamnoides (Rossmässler) Kvaček et Walther

3. Incomplete leaf impression, Monte Tondo MSF1989, scale bar 10 mm.
4. ? Complete leaf, Tossignano MSF1997, scale bar 10 mm.
5. Leaf compression, Tossignano M.D. 4663, scale bar 10 mm.

cf. *Photinia* sp.

6. Leaf base, Monte Tondo MSF1842, scale bar 10 mm.
7. Complete leaf impression, Monte Tondo MSF1846, scale bar 10 mm.
8. Large leaf, Monte Tondo MSF1843, scale bar 10 mm.

Fagus gussonii Massalongo emend. Knobloch et Velitzelos

9. Short leaf impression, Tossignano MSF47, scale bar 10 mm.
10. Incomplete leaf impression, Tossignano MSF25, scale bar 10 mm.
11. Leaf without apex, Monte Tondo MSF1616, scale bar 10 mm.
12. Broader leaf impression, Monte Tondo MSF1610, scale bar 10 mm.

PLATE 9

Myrica lignitum (Unger) Saporta

1. Long petiolate narrow leaf base, Monte Tondo MSF1829, scale bar 10 mm.
2. Narrow leaf base, Monte Tondo MSF1828, scale bar 10 mm.
3. Complete leaf impression, Monte Tondo MSF1827, scale bar 5 mm.

Salix sp.

4. Leaflet, Monte Tondo MSF1607, scale bar 10 mm.
5. Detail of the previous figure 4, scale bar 5 mm.

Engelhardia (sect. *Palaeocarya*) *macroptera* (Brongniart) Unger

6. Fruit with involucre, Monte Tondo MSF1606, scale bar 10 mm.

Pterocarya paradisiaca (Unger) Iljinskaya

7. Leaflet base, Tossignano MSF30, scale bar 10 mm.
8. Leaflet without apex, Monte Tondo MSF1544, scale bar 10 mm.

Carya sp.

9. Leaflet, Monte Tondo MSF1902, scale bar 10 mm.
10. Counter-impression of the previous leaflet, Monte Tondo MSF1903, scale bar 10 mm.
11. Detail of the previous Fig. 10, scale bar 5 mm.

cf. *Betula* sp.

12. Leaf impression, Monte Tondo MSF1530, scale bar 5 mm.

Alnus cecropiifolia (Ettingshausen) Berger

13. Leaf impression without base, Tossignano MSF260, scale bar 10 mm.

Alnus cf. *menzelii* Raniecka-Bobrowska

14. Leaf impression without apex, Monte Tondo MSF1524, scale bar 10 mm.

PLATE 10

Carpinus cf. *betulus* Linnaeus

1. Fruit with involucre, Tossignano MSF607, scale bar 5 mm.

Carpinus cf. *orientalis* Miller.

2. Fruit with involucre, Monte Tondo MSF1535, scale bar 5 mm.

Ulmus plurinervia Unger

3. Elongate leaf, Monte Tondo MSF1533, scale bar 10 mm.

Fagus gussonii Massalongo emend. Knobloch et Velitzelos

4. Broader leaf, Tossignano MSF32, scale bar 10 mm.

Salix sp.

5. Leaf impression, Monte Tondo MSF1951, scale bar 10 mm.
6. Leaf impression without tip, Monte Tondo MSF1952, scale bar 10 mm.
7. Detail of the previous figure 6, scale bar 5 mm.

cf. *Populus* sp.

8. Bract, Tossignano MSF243, scale bar 2.5 mm.

Acer cf. *integrilobum* Unger

9. Large leaf, Monte Tondo MSF1501, scale bar 10 mm.
10. Smaller leaf, Monte Tondo MSF1509, scale bar 10 mm.

Acer sp.

11. Fruit, Monte Tondo MSF1506, scale bar 5 mm.
12. Fruit, Tossignano MSF244, scale bar 5 mm.

Acer cf. *integerrimum* (Viviani) Massalongo

13. Leaf base, Monte Tondo MSF1504, scale bar 10 mm.
14. Long petiolate leaf, Monte Tondo MSF1507, scale bar 10 mm.

PLATE 11

Chaneya cf. *membranosa* (Goeppert) Manchester et Zastawniak

1. Presistant pentamerous corolla, Monte Tondo MSF1550, scale bar 5 mm.

cf. *Ailanthus pythii* (Unger) Kovar-Eder et Kvaček

2. Leaflet, Monte Tondo MSF1520, scale bar 5 mm.
3. Leaflet, Tossignano MSF218, scale bar 10 mm.
4. Leaflet, Monte Tondo MSF1511, scale bar 10 mm.

cf. *Nyssa* sp.

5. Leaf fragment, Monte Tondo MSF1832, scale bar 10 mm.

Nyssa disseminata (Ludwig) Kirchheimer

6. Endocarp impression, Monte Tondo MSF1830, scale bar 5 mm.

cf. *Nyssa* sp.

7. Leaf fragment, Monte Tondo MSF1833, scale bar 10 mm.

cf. Theaceae gen. et sp. indet.

8. Leaf impression, Monte Tondo MSF1988, scale bar 10 mm.
9. Detail of the previous Fig. 8, scale bar 5 mm.

Hedera sp.

10. Leaf impression, Monte Tondo MSF1618, scale bar 10 mm.
11. Detail of the previous Fig. 10, scale bar 5 mm.

Pungiphyllum cruciatum (A. Braun) Frankenhäuser et Wilde

12. Leaf impression, Monte Tondo MSF1905, scale bar 10 mm.
13. Leaf base, Monte Tondo MSF1904, scale bar 5 mm.

PLATE 12

Phyllites sp.

1. Leaf fragment, Monte Tondo MSF1849, scale bar 10 mm.

Carpolites sp. 1

2. Impression of disseminule may represent a cone of *Tetraclinis*, Monte Tondo MSF1543, scale bar 2.5 mm.
3. Impression of disseminule, Monte Tondo MSF1537, scale bar 2.5 mm.

Carpolites sp. 2

4. Impression and counterimpression of seed, Monte Tondo MSF1539–1540, scale bar 2.5 mm.

Carpolites sp. 3

5. Impression may represent an isolated seed of *Pinus*, Tossignano MSF242, scale bar 2.5 mm.

Plant incertae sedis

6. ? Tendril, Monte Tondo MSF1542, scale bar 5 mm.

Dicotylophyllum sp. 1

7. Leaf impression, Monte Tondo MSF1596, scale bar 5 mm.
8. Leaf impression, Monte Tondo MSF1597, scale bar 5 mm.

Dicotylophyllum sp. 6

9. Leaf impression, Monte Tondo MSF1589, scale bar 5 mm.

Dicotylophyllum sp. 2

10. Leaf impression, Tossignano MSF620, scale bar 5 mm.

Dicotylophyllum sp. 3

11. Obovate entire-margined leaf impression, Tossignano MSF279, scale bar 10 mm.

Dicotylophyllum sp. 4

12. Small rounded leaf, Monte Tondo MSF1600, scale bar 5 mm.

Dicotylophyllum sp. 5

13. Leaf or leaflet, Monte Tondo MSF1602, scale bar 5 mm.

cf. *Photinia* sp.

14. Leaf impression, Monte Tondo MSF1848, scale bar 10 mm.

Dicotylophyllum sp. 7

15. Leaf impression, Monte Tondo MSF1603, scale bar 5 mm.

Dicotylophyllum sp. 8

16. Leaf impression, Monte Tondo MSF1531, scale bar 5 mm.

PLATE 1

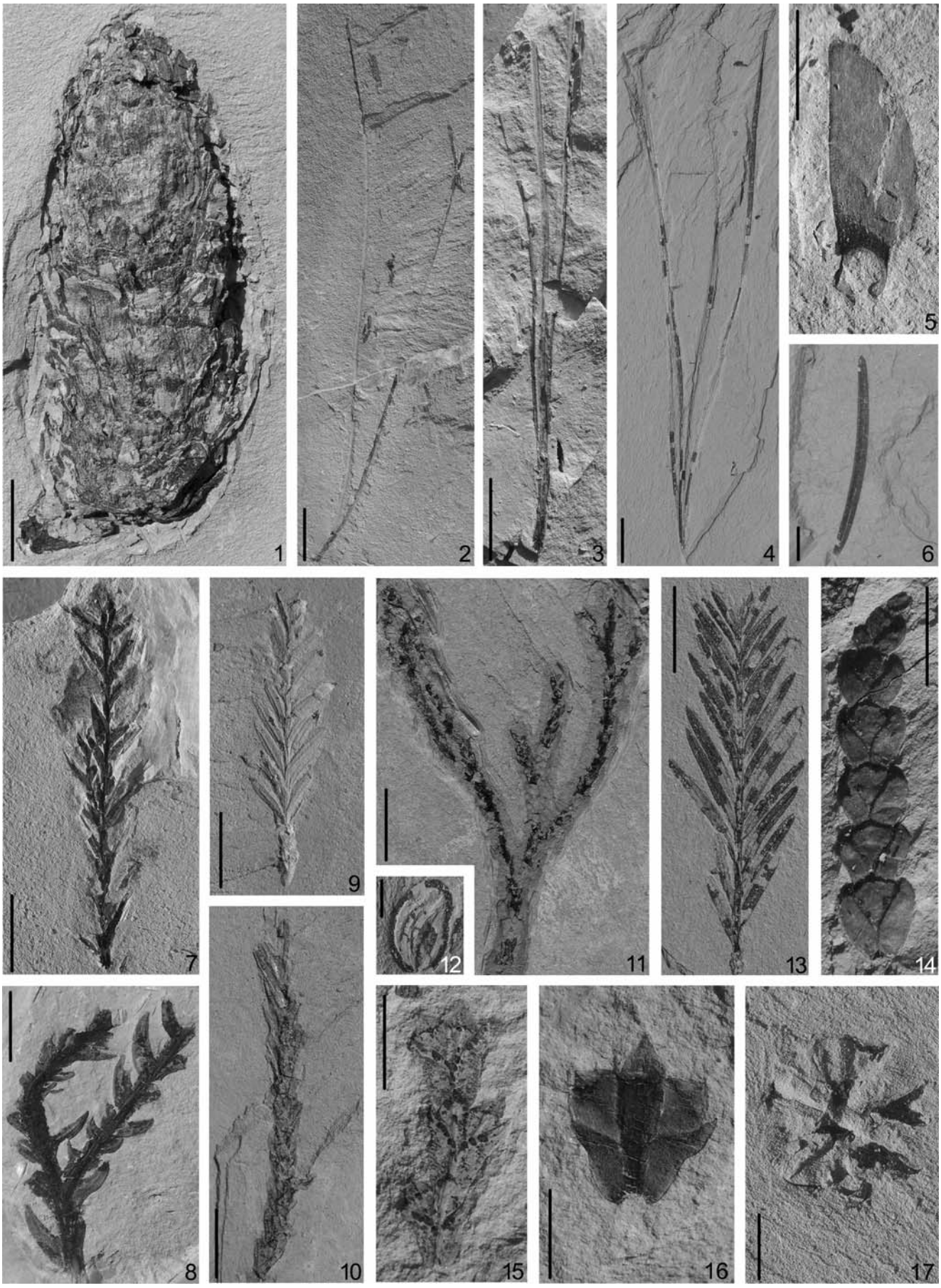
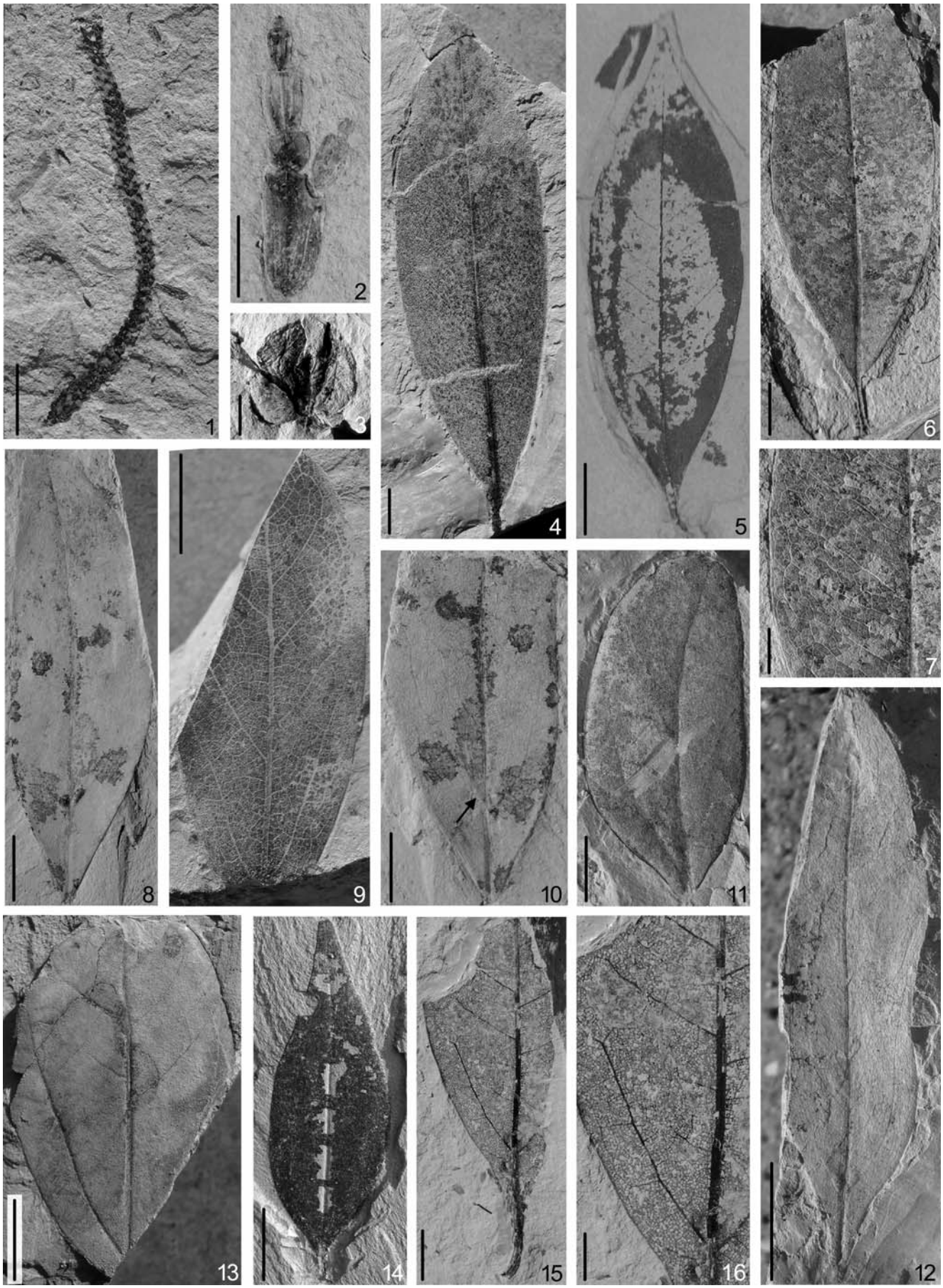
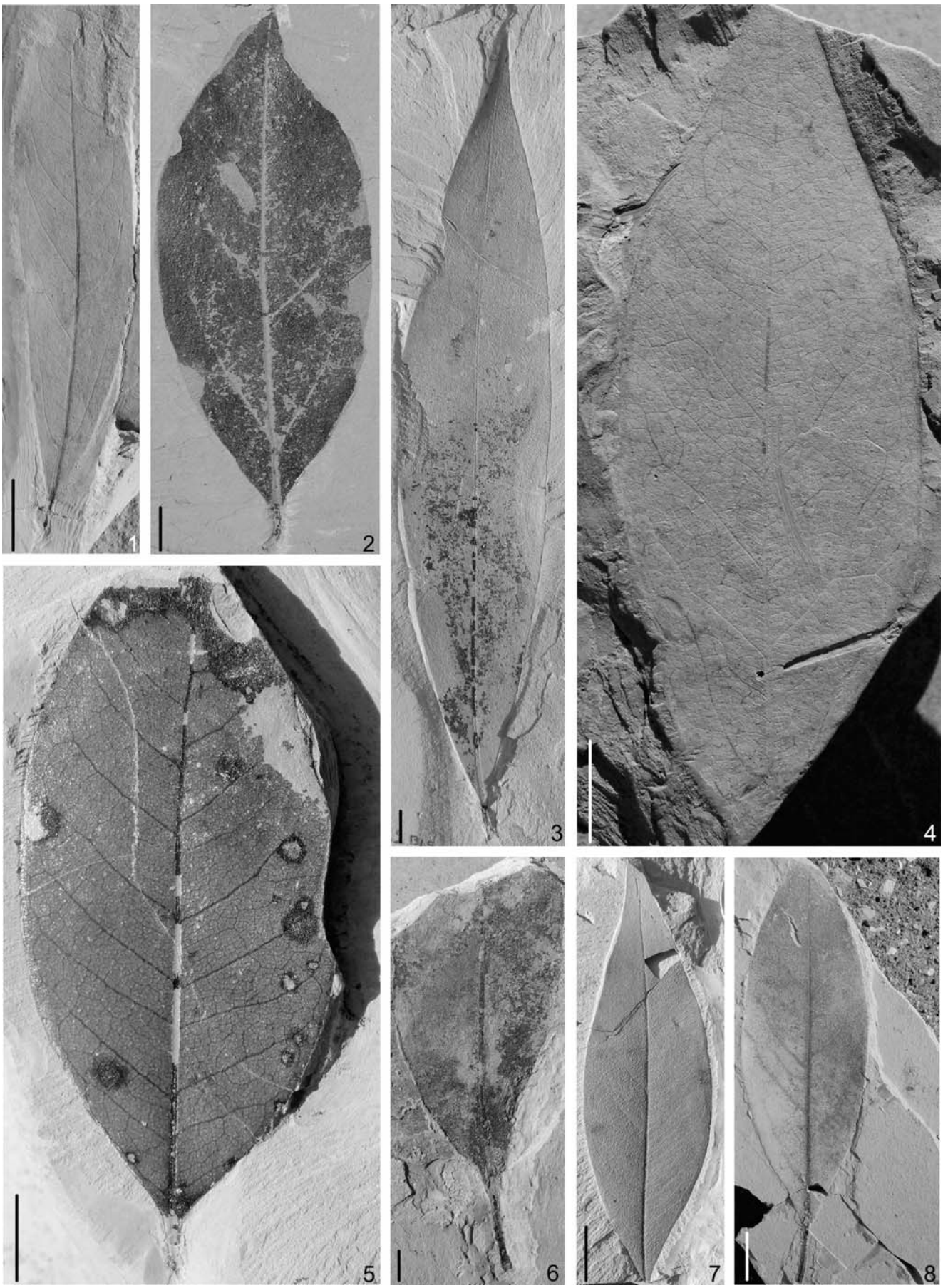


PLATE 2

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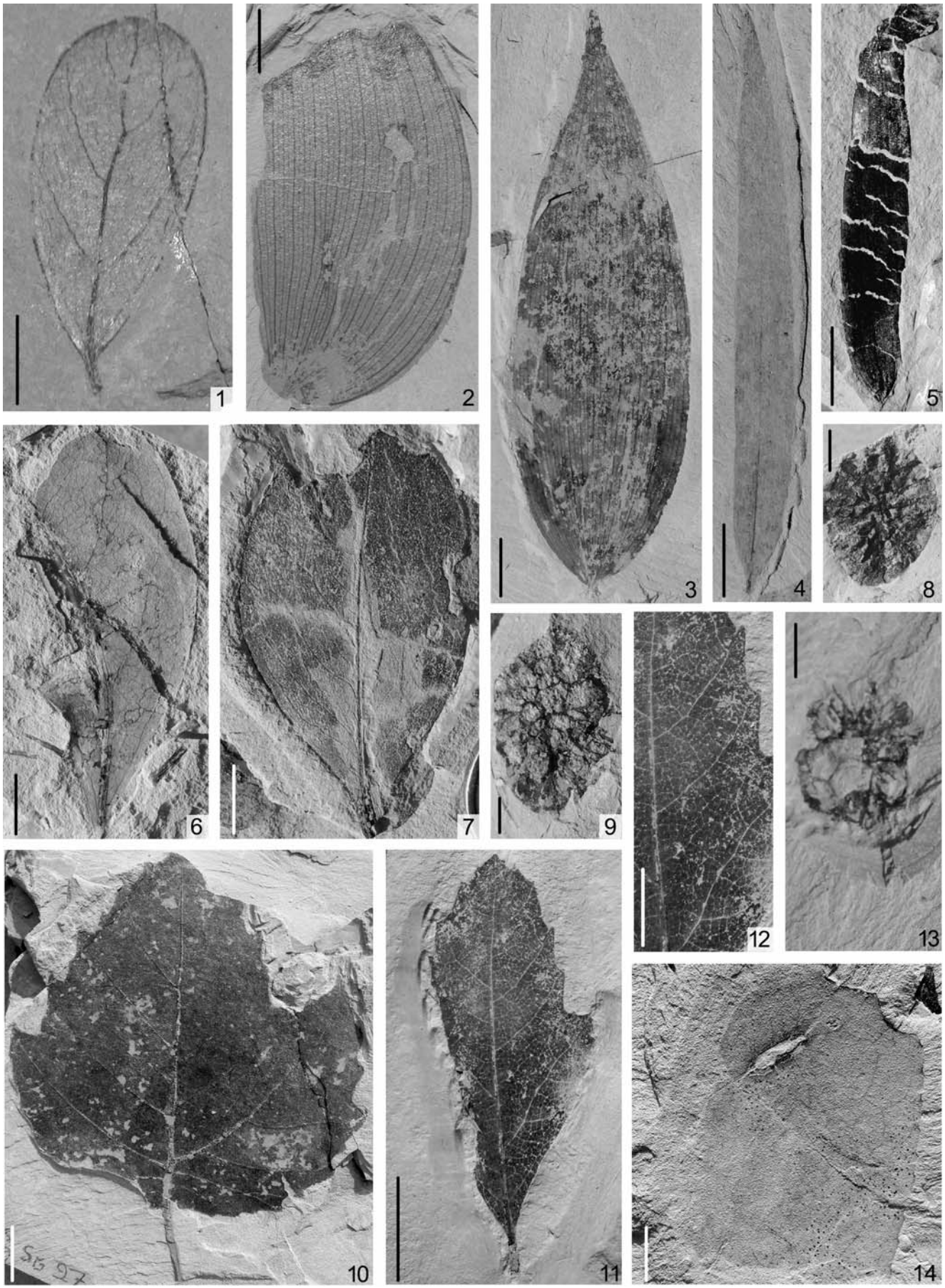

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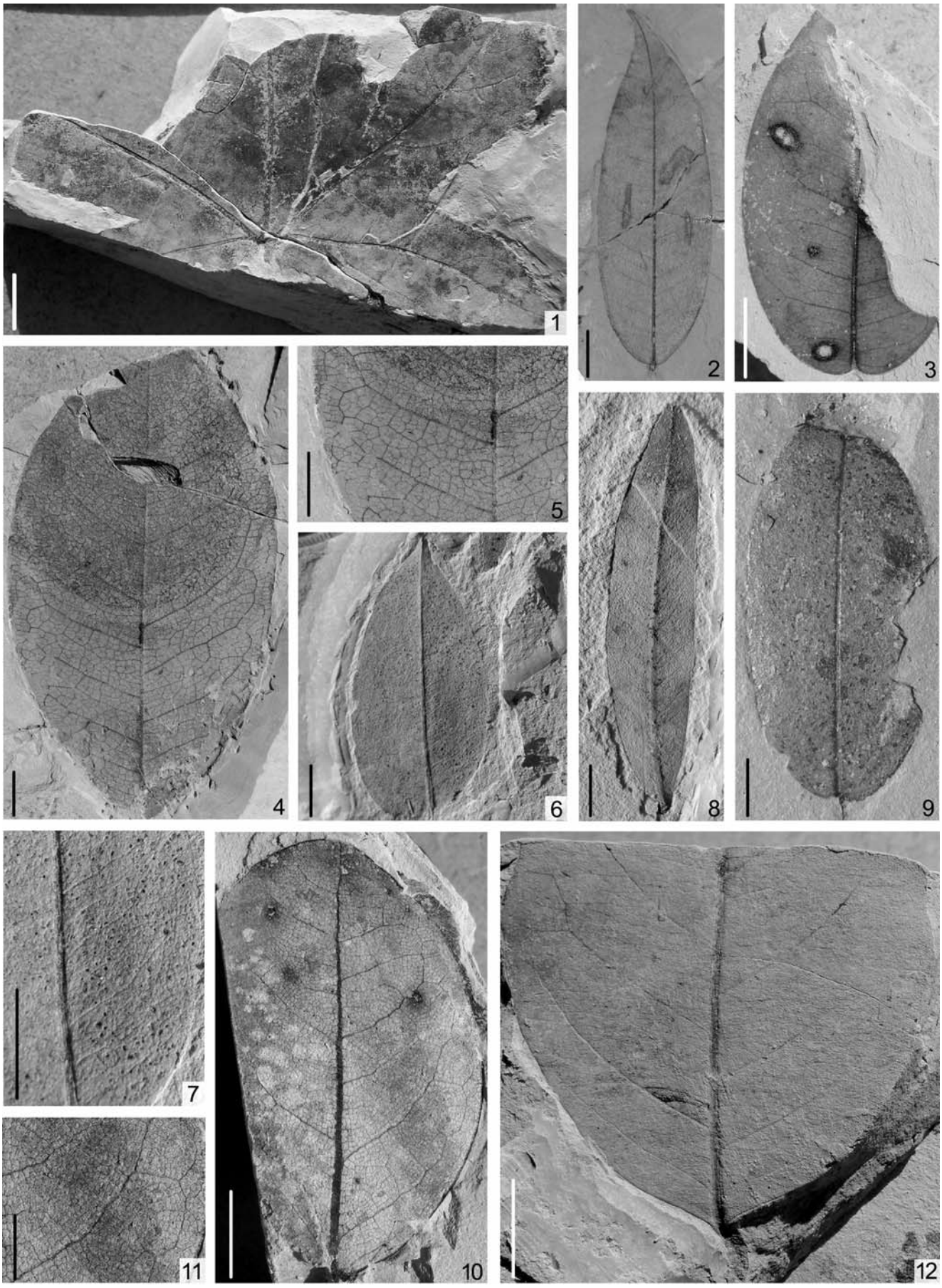
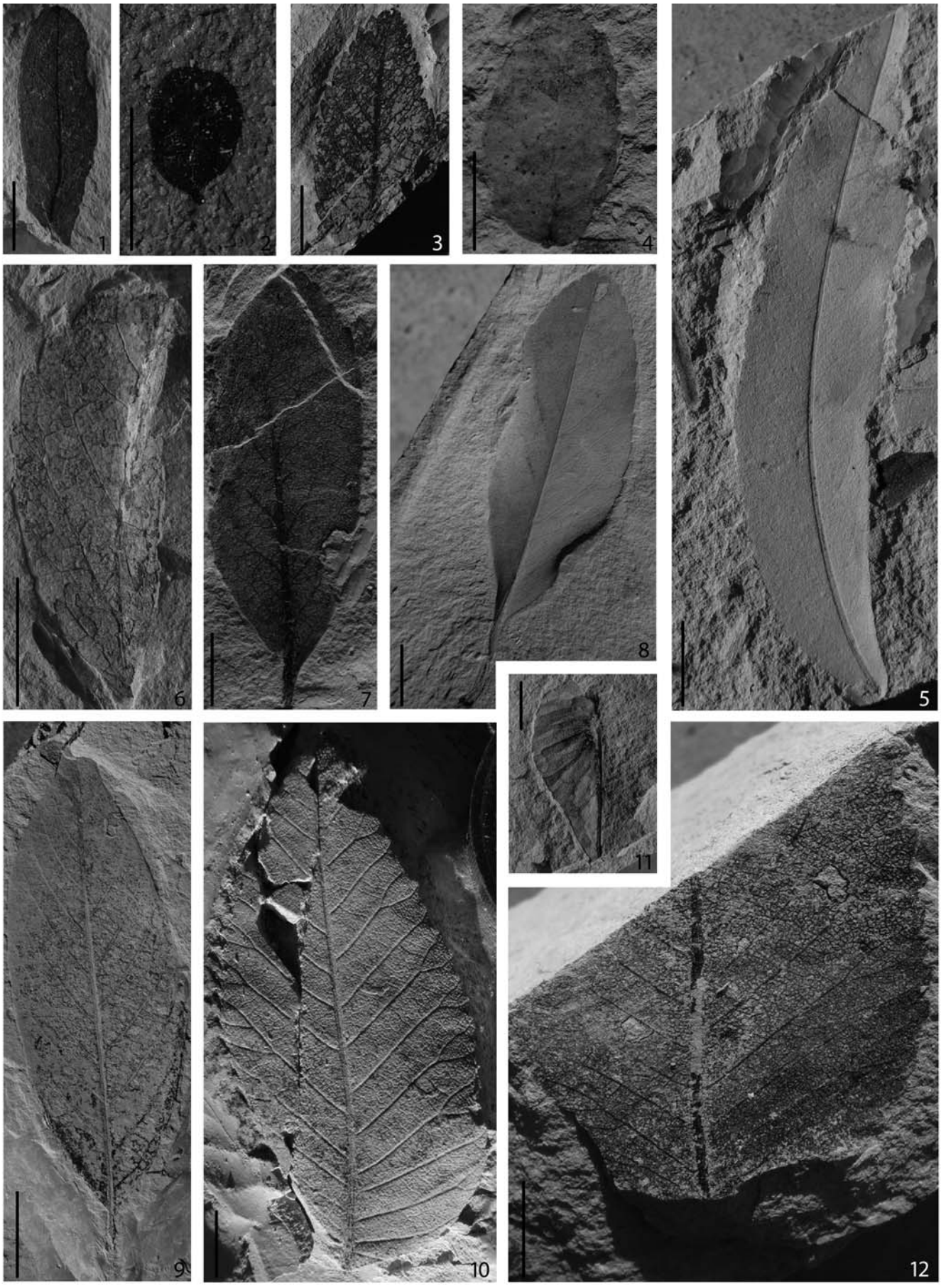


PLATE 6



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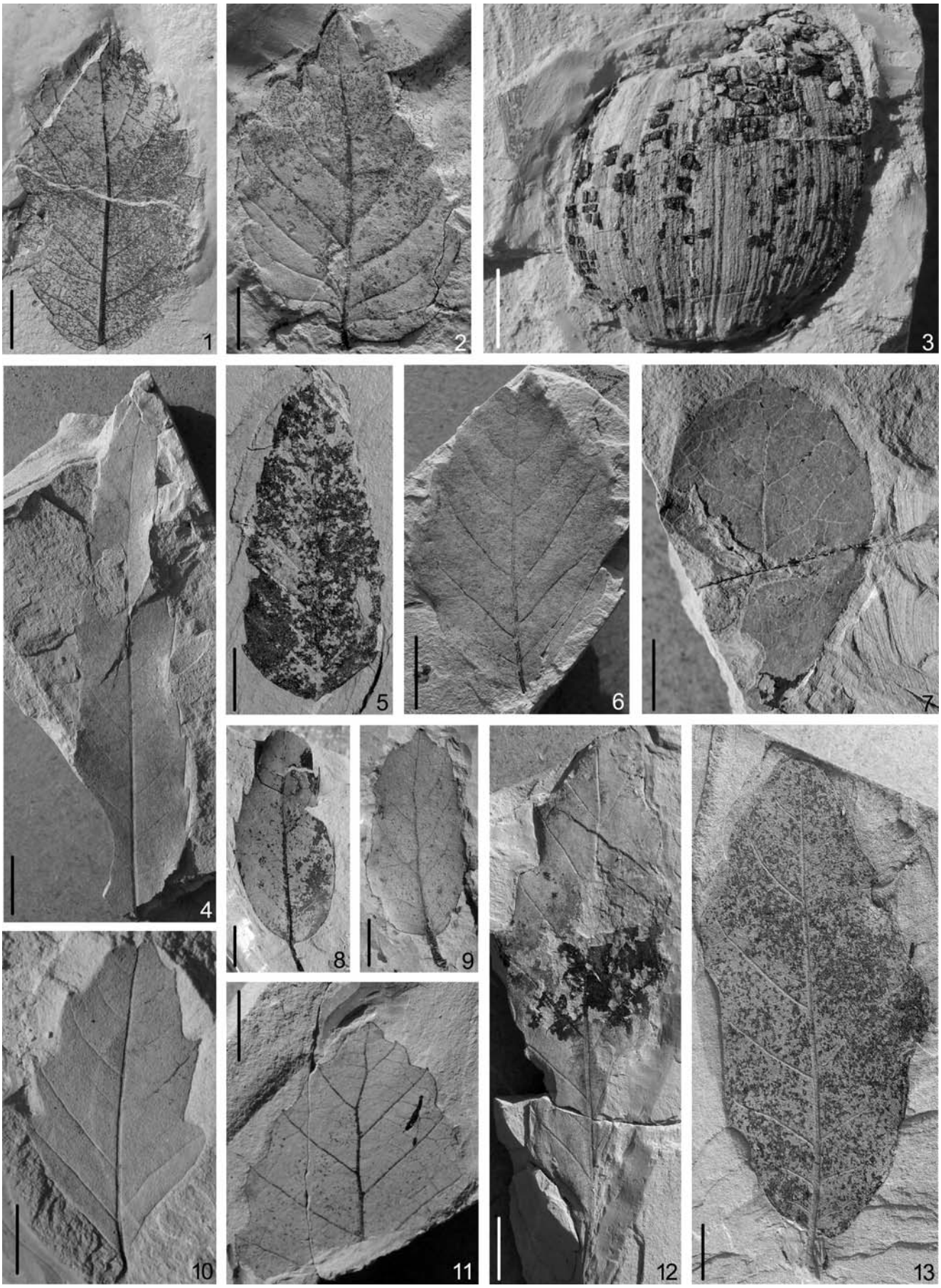

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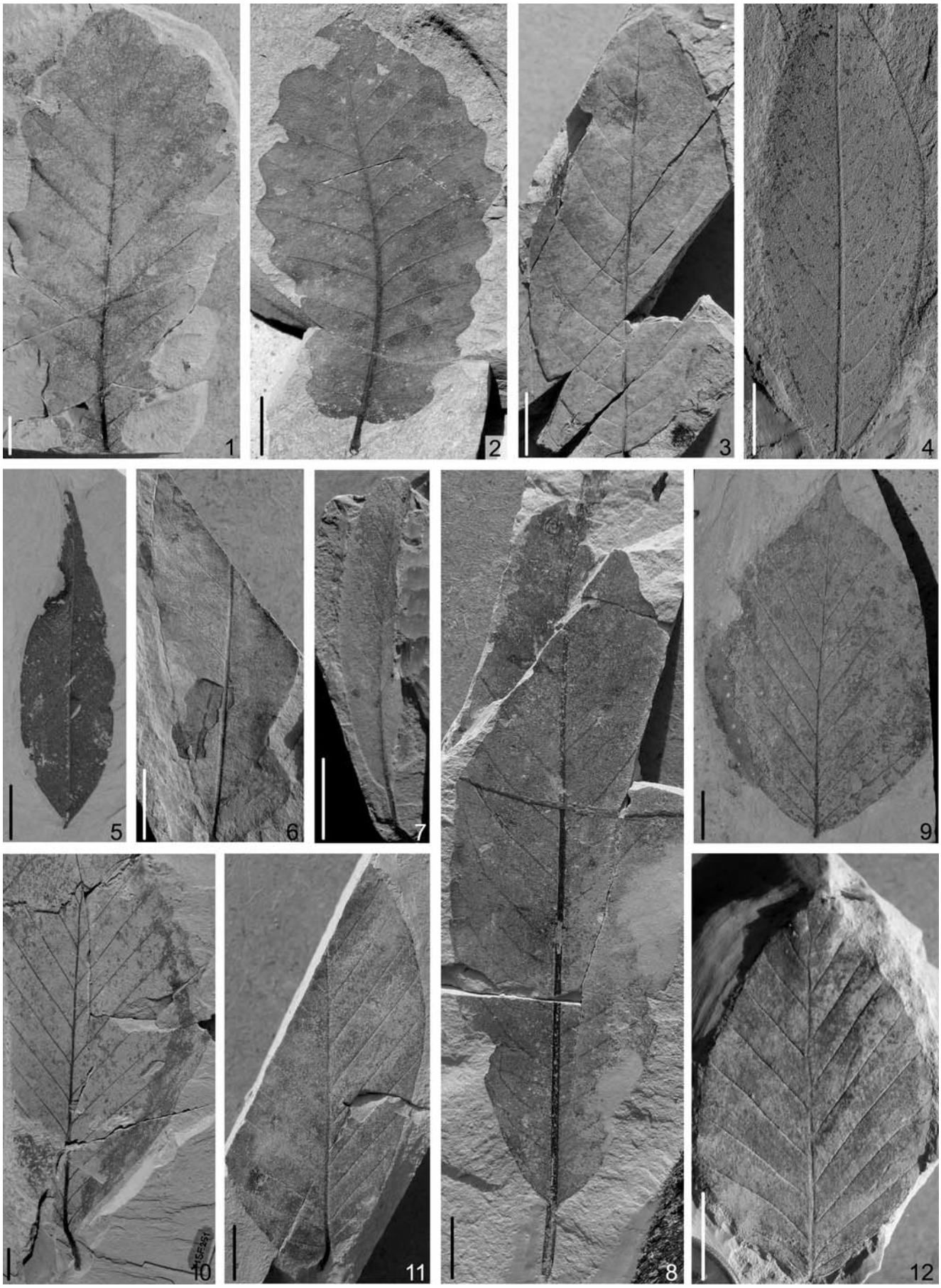

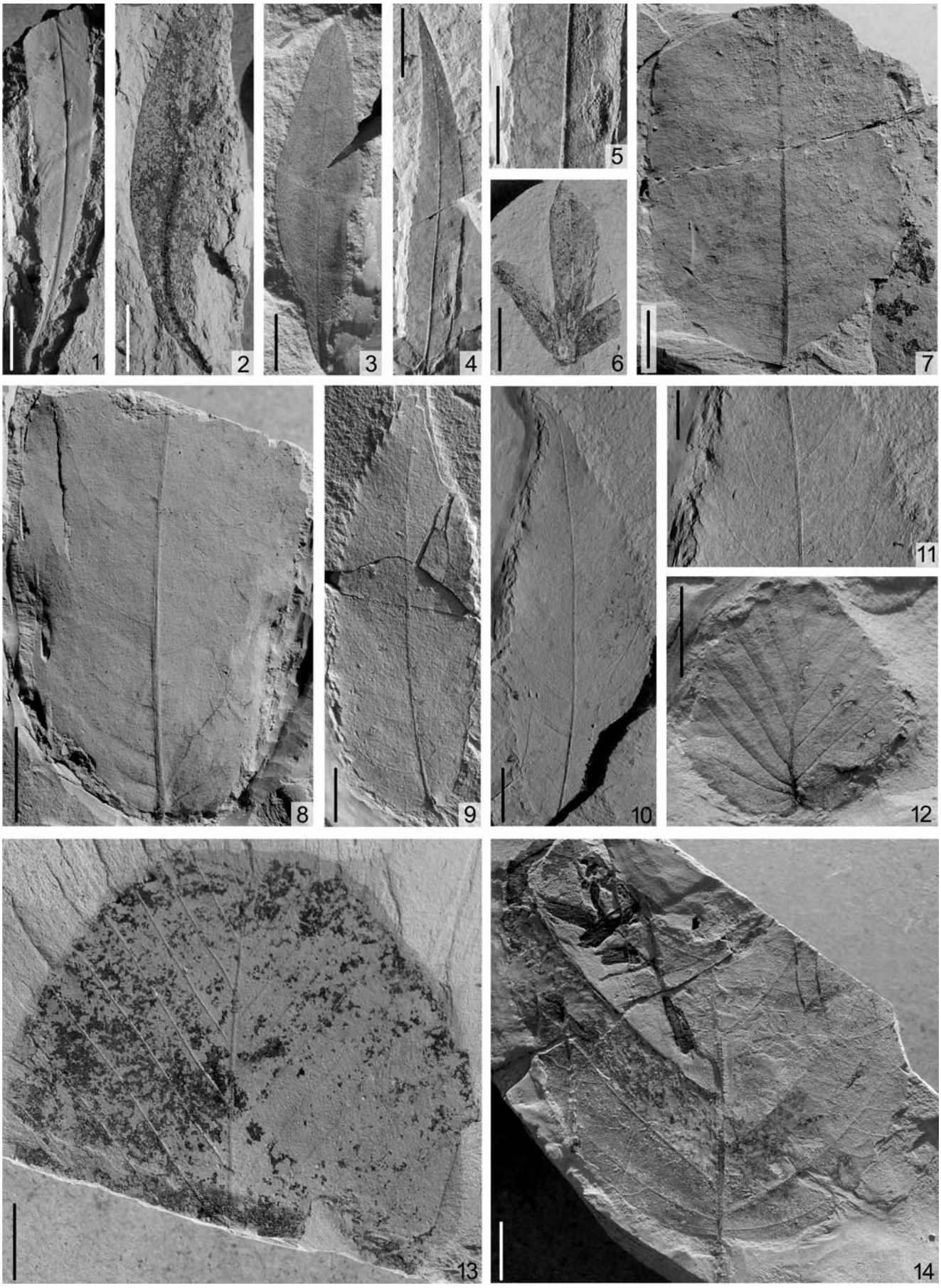
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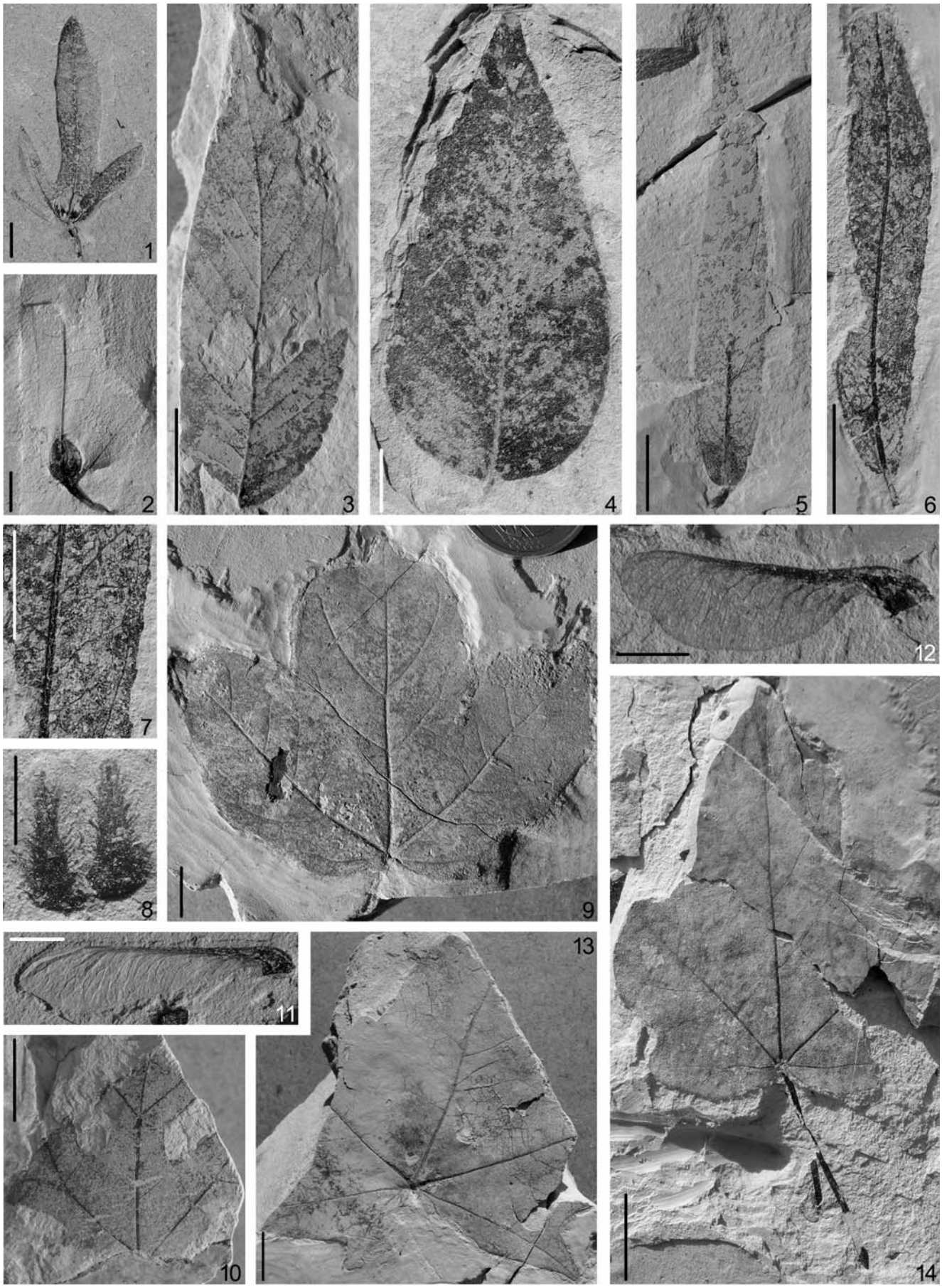
PLATE 10



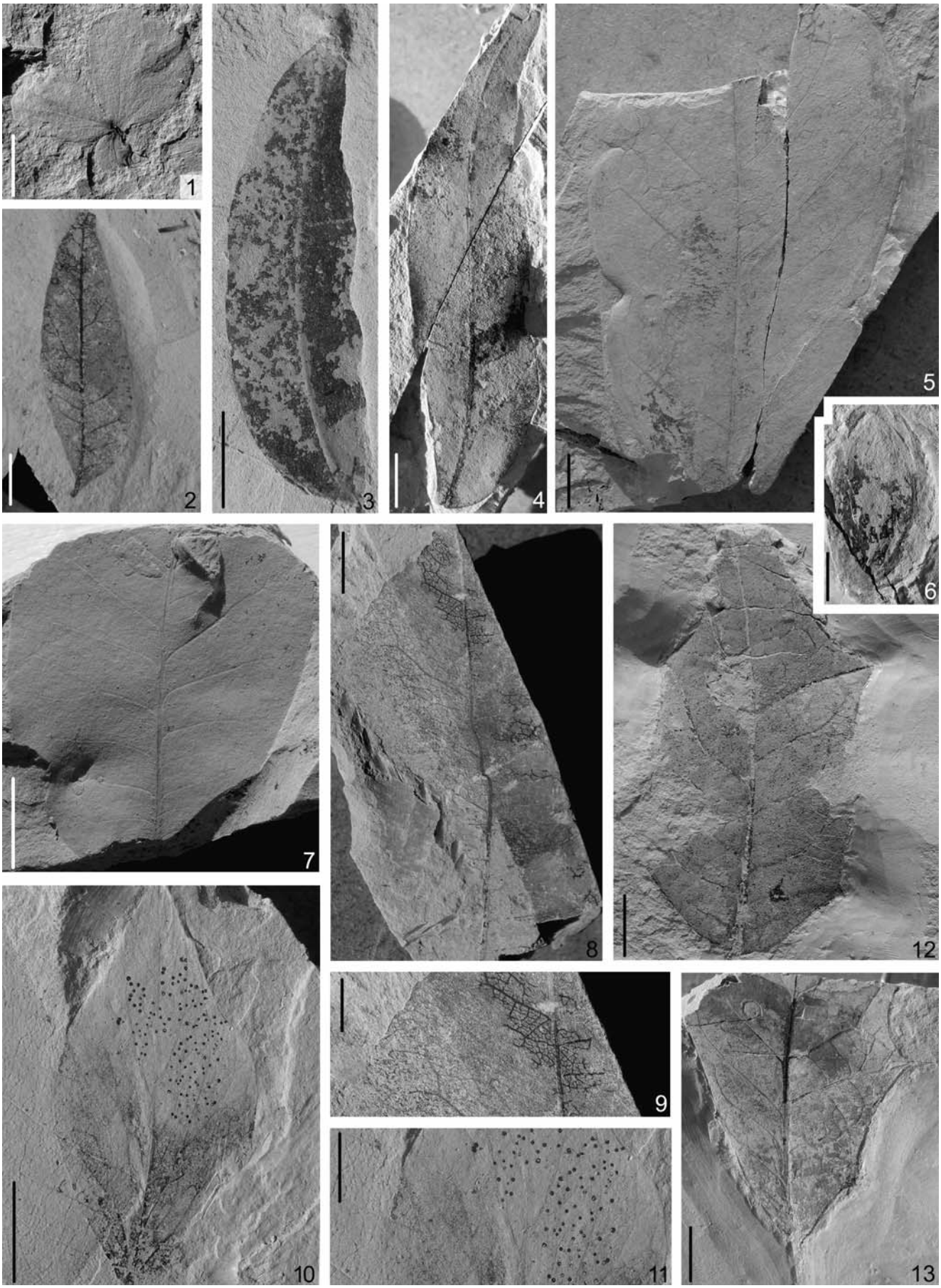

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PLATE 12